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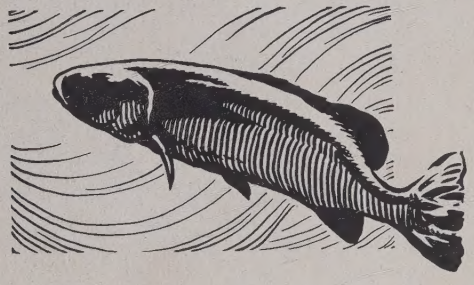

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EXPERIMENTS WITH METHODS FOR AIR TRANSPORT OF LIVE FISH

Carl M. Nemoto
Board of Commissioners of Agriculture and Forestry
Honolulu, Hawaii

THE PROBLEMS INVOLVED IN THE SUCCESSFUL AND EFFICIENT TRANSPORT OF LIVE FISH have been of interest to aquariums, tropical-fish dealers, home aquarists, conservation and management agencies, and fishery research institutions. In the past, the Division of Fish and Game (Territory of Hawaii) has had several occasions to receive and ship fish and has been concerned with a method of shipment each time. Immediately after World War II some fish were brought into the Territory in large fresh-water tanks installed on steamships, and care was given these fish every day throughout the several days' voyage from the mainland to Honolulu. Subsequent shipments for distribution to the various islands of the Territory were made by air in 20-gallon cans covered to prevent splashing and spilling. The covers were equipped with an air vent through which an aeration line could be inserted until the cans were loaded on the plane. Only a few fish at a time could be shipped; the cans had to be filled to the top with water, which added considerably to the weight of the container and consequently made transport by air cumbersome and expensive. There were a few occasions when fish were transported between islands in the live well of the Fish and Game Division's research vessel. This required trained personnel to tend to the fish throughout the trip.

The Division of Fish and Game, with the anticipation of further introduction and distribution problems associated with the introduction and distribution program of exotic fresh-water game fish, began in July 1953 a series of experiments on methods of keeping fish in sealed containers for transport primarily by air.

The objective of these experiments was to devise a shipping method with the following features:

1. The container with the fish to be sufficiently light for air transport; thus, water requirements for any given weight of fish had to be minimal.
2. The method to be simple and inexpensive, without requiring complex or expensive equipment.
3. A technique adequate to maintain the fish in the container for a period long enough for shipment from most parts of the world by air.

It was apparent that, to avoid damage to other air cargo, any fish shipped by commercial air transport had to be in sealed containers. Therefore, problems due to keeping fish in a completely sealed container had to be solved first. These problems were, first, provision of an adequate oxygen supply; and second, the prevention of contamination of the water through the accumulation of metabolic products. It

This work was undertaken with Federal Aid in Fish Restoration funds, as part of Dingell-Johnson Project F-4-R, Hawaii.

was believed that the solution of these problems--an adequate oxygen supply and control of the metabolic products--would be essential to the development of an efficient shipping method. A series of experiments was then designed to observe the effects on the survival time--of bluegill (Lepomis macrochirus), largely, in sealed containers--of:

1. Increasing oxygen supply by (a) replacing air with pure oxygen, (b) maintaining a high oxygen pressure in the container, and (c) reducing the rate of oxygen consumption.
2. Controlling metabolism and metabolic products by (a) reducing the rate of metabolic waste discharge, and (b) neutralizing or eliminating certain products discharged.

After development of a suitable method, the technique (with slight modifications if necessary) could then be applied to shipment of other species of fish when the need arose. Some experiments were also conducted with Tilapia mossambica.

For most of the experiments in the laboratory, a 2.5-gallon wide-mouthed glass jar was used as the sealed container. It was equipped with a plastic (lucite) top that could be clamped on tight to make a hermetic seal. This top was equipped with gas fittings to allow the introduction of oxygen and the release of excess water displaced by the oxygen. A third valve was installed for connection to an open mercury manometer for pressure readings. The operation of the apparatus consisted of filling the jar to the brim with water, introducing fish, and then clamping on the cover. After this, oxygen was introduced through the valve so as to displace the water through an outlet valve. A measure of the volume of displaced water supplied the measure of the volume of oxygen introduced. An arbitrarily selected volume of 5.4 liters of water was replaced; a volume of approximately 4 liters was left in the jar. When the determined amount of water had been replaced, the outlet valve was closed and the oxygen pressure in the jar built up to the desired amount. In consideration of the fact that the jar was made of glass, a pressure of not more than 10 pounds per square inch was used for experiments involving pressure and this container.

Plastic (polyethylene) bags were also extensively used for some of the holding experiments. A volume of 4 liters of water was used in the 16-liter bags, and a measured amount of fish was introduced and subjected to various experimental treatments. When oxygen was used, the bag was simply flattened to the water surface and inflated with oxygen. The opening of the bag was then securely tied, doubled over, and tied again to make an airtight seal.

For experiments subjecting the fish to high oxygen pressures, an experimental high-pressure chamber was devised and used. It was constructed from an old sleeve of the type used for steam lines in hospitals, industrial plants, and steamships; it was designed for a working pressure of 250 pounds per square inch or less. Lucite plates, 1 inch thick, were bolted on each end to permit observation of its contents. For introduction of the fish into this container, the plate was removed from one end; then the plate was bolted on again to make a hermetic seal. Gas fittings were installed on the container to make its operation similar to that of the jar. A pressure gauge was also mounted on the sleeve for a direct reading of the pressure. The container had a capacity of 6.5 liters, in which a volume of 3 liters of water was displaced for the high-pressure tests.

Certain experiments were also performed in open gallon jars and aquaria.

The water used in the entire series of experiments came directly from the city water system. The water had a pH of about 7.5, oxygen content of about 5.16 to 6.24 cubic centimeters per liter, and an average temperature of about 75° F.

A series of experiments was performed with these containers to observe the effects of various treatments on survival time. The holding experiments were stopped at what was considered an "end point," when it appeared that the fish

TABLE 1.--Survival time with air and with pure oxygen

Number of fish	Approximate size (cm.)	Weight (gm.)	Time (hrs.)	Oxygen (cc./l.)	Carbon dioxide (mg./l.)	pH	Number dead	Treatment
45	3.5 - 8	110.4	3	0.69	9.90	6.95	5	Air (jar)
6	8 - 12	110.8	4	0.64	7.90	6.90	0	Air (jar)
22	5 - 10	200.6	4	0.66	11.66	6.82	1	Air (bag)
33	4.5 - 8.5	108.3	22	8.34	35.20	6.75	0	Oxygen (jar)
22	4.5 - 12	113.7	57	2.24	118.80	6.30	0	Oxygen (jar)
27	3 - 8	193.9	75	1.15	97.35	6.50	3	Oxygen (bag)
51	4 - 5	200.0	40	1.57	53.68	6.60	0	Oxygen (bag)

would be lost if subjected to a treatment for a longer period. In other words, the objective was to subject the fish to a treatment for the longest time possible without causing any mortality. It was obvious that the rate at which each fish would be affected by the treatments was variable, and hence that the reaction of the fish to a treatment would be variable. It was therefore difficult to make precise and consistent determinations of the distress point for each test; for certain tests, it is conceivable that errors of as much as 10 hours (approximately 10 to 15 percent) were made in estimating the "end point" of the experiment. Also, it was not uncommon that during a test a few fish died before the rest showed the slightest distress. The test in such a case was continued until the distress reaction was displayed by the remaining fish. It is suspected that the "end point" was influenced by putrifaction of the dead fish in these experiments, but no conclusive evidence to that effect is available.

EFFECTS OF INCREASED OXYGEN ON SURVIVAL TIME

It would seem logical to point out that lack of oxygen might well be the initial limiting factor for fish shipments, especially in a sealed system. It is common knowledge that the gas most essential for sustenance of life is oxygen, and that the atmosphere contains but 20 percent of this gas. It is obvious, therefore, that the replacement of air with pure oxygen would increase the supply of oxygen in the shipping container by a factor of 5. Equal amounts of fish by weight were tested in the jar and in the plastic bags, and the effects of oxygen were compared with air. Table 1 shows an increase of 20 to 70 hours in survival time by replacement of air with pure oxygen.

To investigate further the effects of oxygen on fish in a sealed container, tests with high oxygen pressures were made in the high-pressure chamber. Beginning at pressures of 15 pounds per square inch, the fish immediately displayed signs of air-bladder trouble and sank to the bottom. Initially, 250 grams of fish in 3.5 liters of water was subjected to oxygen pressures of 50 to 60 pounds per square inch. For the duration of the experiment, they sank to the bottom, where they remained motionless, with the action of respiration the only visible evidence of life. Before the end of 24 hours, they all were dead. The same tests performed with less fish (50 grams) produced the same reaction and results. In one of this series of tests using 50 grams of fish, the pressure was reduced from 60 to 15 pounds per square inch after 16 hours, but there was no improvement in the results. The fish were dead in less than 24 hours.

It was believed that impurities which were lethal to the fish might have remained within the container. This possibility was tested by circulating city water at a pressure of 70 pounds per square inch through the container with 133 grams of fish.

TABLE 2.--Effect of pollution by metabolic waste accumulation

Number of fish	Size (cm.)	pH	Oxygen (cc./l.)	Nonprotein nitrogen (mg.%)	First death	Last death
4	7 - 8	7.5	8.54	1.2	2.5 hrs.	3 hrs.
4	7 - 8	7.5	8.51	2.2	2.25 hrs.	2.5 hrs.
4	7 - 8	7.1	8.55	2.7	45 mins.	1.5 hrs.
4	7 - 8	7.2	8.54	5.4	10 mins.	20 mins.

The reaction of the fish in all cases indicated their inability to withstand high pressure, and for that reason the experiments with high pressures were discontinued. When any degree of pressure was required, not more than 10 pounds per square inch was applied.

All of the high-pressure experiments were made with bluegill.

EFFECTS OF POLLUTION BY METABOLIC WASTE ACCUMULATION

The effects of pollution by metabolic waste accumulation on the bluegill were tested in the laboratory. At the completion of holding experiments in the plastic bags, the fish were removed and the water was filtered into 4 wide-mouthed gallon jars that contained NPN (nonprotein nitrogen)[1/] concentrations of 1.2, 2.2, 2.7, and 5.4 milligrams percent, respectively. The water was then aerated, and after 3 hours 4 fish of equal sizes were put into each jar with continued aeration to eliminate oxygen as the limiting factor. All the fish were dead within 15 minutes to 3 hours; the fish in the jar having the lowest NPN concentration lasted longest (table 2).

The exact nature of the toxin was not investigated, although Brockway (1950) mentioned the toxic nature of metabolic products to the trout and its extreme sensitivity to both ammonia and ammonium compounds. Regardless of what the exact substance might be, it was certain that there existed products of metabolic discharges that were highly lethal to the fish.

[1/] The digestion process was eliminated, and the determinations of NPN concentrations were made by direct nesslerization. Representations of NPN values, were, therefore, actually measures of ammonia concentrations and were so represented with the assumption that the other products of metabolic discharges were in direct proportion.

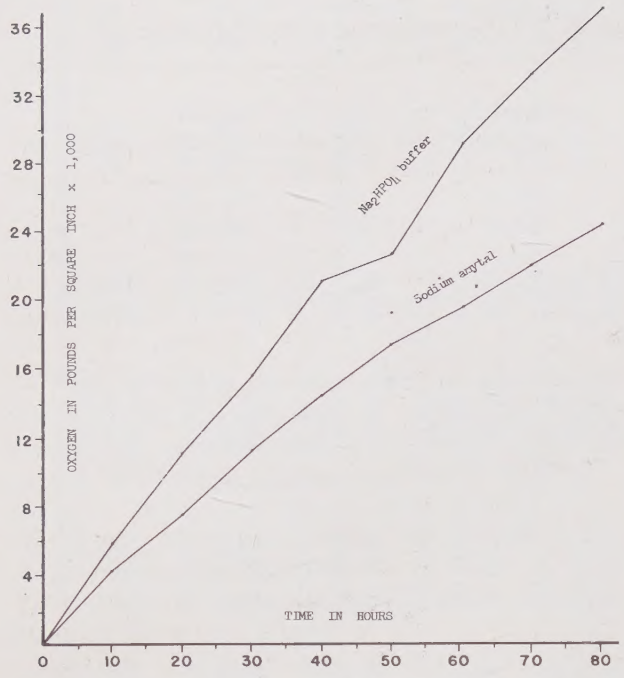
USE OF SODIUM AMYTAL

The California Department of Fish and Game announced successful use of sodium amytal, a slow-reacting, long-lasting barbiturate, for the transport of trout (1953). The Department of Fish and Game found that this sedative calmed the fish to such an extent that they used less oxygen and thereby permitted an increase in the carrying capacity of fish per gallon of water without any apparent harmful after-effects on the fish.

The tranquilizing effect of this drug at a concentration of 1 grain per 4 liters of water was tested on bluegill. As shown in table 3, two oxygen consumption rate determinations were made using sodium amytal, and three determinations using the Na_2HPO_4 buffer without sodium amytal. The oxygen pressures in all tests were built up in the jar to start at a mercury height difference of 50.0 centimeters in the manometer. Manometer readings were taken at intervals of 10 hours during the test, which lasted 80 hours. For the 80-hour period, mean oxygen consumption in pounds per square inch per gram of fish in the buffer tests and mean oxygen consumption per gram of fish in the sodium amytal tests were then computed and graphically illustrated (see figure). The results showed a definite reduction in the rate of oxygen consumption through the

TABLE 3.--Oxygen consumption rate: Oxygen and buffer compared with oxygen and sodium amytal

Time (hrs.)	Amount of fish (gm.)		Mercury height difference at reading (cm.)		Oxygen consumed mercury height difference (cm.)		Oxygen consumed (lbs./sq.in.)		Oxygen consumed (lbs./sq.in. per gm. fish x 1,000)		Mean	
	Buffer	Amytal	Buffer	Amytal	Buffer	Amytal	Buffer	Amytal	Buffer	Amytal	Buffer	Amytal
10	163	160	43.5	46.9	7.5	4.1	1.467	0.800	9.0	5.0		
	160	200	46.5	47.5	4.5	3.5	.880	.680	5.5	3.4	5.9	4.2
	150	---	48.6	----	2.4	---	.465	-----	3.1	---		
20	163	160	36.5	43.9	14.5	7.1	2.836	1.392	17.4	8.7		
	160	200	43.0	44.4	8.0	6.6	1.568	1.300	9.8	6.5	11.1	7.6
	150	---	46.3	----	4.7	---	.930	-----	6.2	---		
30	163	160	30.6	40.0	20.4	11.3	3.994	2.160	24.5	13.5		
	160	200	40.0	41.7	11.0	9.3	2.160	1.820	13.5	9.1	15.7	11.3
	150	---	44.1	----	6.9	----	1.350	-----	9.0	----		
40	163	160	24.0	37.0	27.0	14.0	5.298	2.752	32.5	17.2		
	160	200	35.8	38.9	15.2	12.1	2.992	2.380	18.7	11.9	21.0	14.5
	150	---	42.0	----	9.0	----	1.770	-----	11.8	----		
50	163	160	18.8	33.7	32.2	17.3	6.308	3.392	38.7	21.2		
	160	200	32.6	37.1	18.4	13.9	3.600	2.720	22.5	13.6	22.6	17.4
	150	---	39.9	----	11.1	----	2.175	-----	14.5	----		
60	163	160	14.2	30.8	36.8	20.2	7.221	3.968	44.3	24.8		
	160	200	29.8	36.2	21.2	14.8	4.160	2.900	26.0	14.5	29.1	19.6
	150	---	38.0	----	13.0	----	2.550	-----	17.0	----		
70	163	160	9.0	27.7	42.0	23.3	8.232	4.576	50.5	28.6		
	160	200	26.7	35.3	24.3	15.7	4.768	3.080	29.8	15.4	33.4	22.0
	150	---	35.9	----	15.1	----	2.970	-----	19.8	----		
80	163	160	5.5	24.9	45.5	26.1	8.916	5.120	54.7	32.0		
	160	200	23.0	33.9	28.0	17.1	5.488	3.360	34.3	16.8	37.1	24.4
	150	---	34.0	----	17.0	----	3.330	-----	22.2	----		



Average oxygen consumption rates recorded from the mercury manometer in pounds per square inch per gram of fish with and without sodium amytal treatment.

(Courtesy of the author)

use of sodium amytal. It seemed safe to assume, therefore, that the resultant catabolic process was also slowed, offering a possibility of increasing the holding time and also of increasing the holding capacity of fish per volume of water by means of the barbiturate.

The results of the holding tests made with sodium amytal in the glass jar and in the plastic bags indicated that it was less effective in increasing the holding time than in increasing the number of fish which could be held (table 4). When the sodium amytal was used, approximately 1 gram of fish to 13 cubic centimeters of water was maintained for more than 90 hours. The application of this method to aquarium fish had already been tested, and it had been reported that with this system only a third of the ordinary amount of shipping water was needed (Innes 1954).

USE OF DIBASIC SODIUM PHOSPHATE BUFFER AND OF CHARCOAL

Vaas (1952), in his experiments with Tilapia mossambica and a method of fish shipment, found that carbon dioxide was a limiting factor on survival time where oxygen had been used to displace the air over the water, and that use of dibasic sodium phosphate (Na_2HPO_4) as a buffer apparently reduced the effect of carbon dioxide and hence increased the holding time. This buffer was tested at a concentration of 1.5 grams per liter of water to maintain the pH level (which is prone to change with the increase of carbon dioxide and other metabolic wastes). The results

TABLE 4.--Holding tests using oxygen, charcoal, and sodium amytal

Number of fish	Approximate size (cm.)	Weight (gm.)	Time (hrs.)	Oxygen (cc./l.)	Carbon dioxide (mg./l.)	pH	Number dead	Remarks
21	3 - 20	149.7	77	4.65	67.65	7.15	4	Jar
25	3 - 18	160.7	74	3.87	69.96	7.00	1	Jar
28	5 - 14	299.8	48	.74	11.31	7.20	6	Jar
20	3 - 30	149.1	96	1.94	36.70	6.90	2	Plastic bag
74	3 - 8	391.6	45	.84	66.35	6.85	0	Plastic bag
31	3 - 14	296.2	93	1.48	70.07	6.75	0	Plastic bag
49	3 - 8	404.2	48	.82	92.95	6.60	1	Plastic bag
55	3 - 8	450.0	48	.67	52.95	6.75	9	Plastic bag
25	4 - 14	297.0	99	.90	48.62	7.20	1	Plastic bag
22	7 - 12	196.6	94	.76	108.46	6.65	0	Plastic bag
41	3 - 8	420.1	93	1.24	43.56	7.25	0	Plastic bag
105	3 - 17	456.7	48	.85	63.86	6.85	9	Plastic bag

TABLE 5.--Use of dibasic sodium phosphate buffer compared with charcoal

Number of fish	Approximate size (cm.)	Weight (gm.)	Time (hrs.)	Oxygen (cc./l.)	Carbon dioxide (mg./l.)	pH	Number dead	Treatment
34	3.5 - 8	156.7	70	2.72	341.22	6.65	7	Oxygen, buffer
24	3 - 8	112.9	69	3.57	196.31	6.70	1	Oxygen, buffer
25	4 - 14	225.0	68	3.78	132.09	6.90	1	Oxygen, buffer
36	3.5 - 8	160.0	88	1.48	108.00	6.75	1	Oxygen, charcoal
7	5 - 50	153.6	70	4.95	10.18	7.20	0	Oxygen, charcoal
19	5 - 14	163.0	96	2.21	107.25	7.05	4	Oxygen, charcoal

were compared with results obtained by using charcoal. Bone charcoal of the type used in aquarium filters was tested in the glass jar and plastic bags. These experiments were made to investigate the possibility that the adsorptive properties of this charcoal would reduce the harmful products of metabolism and thus improve the survival time. It was impossible, without complicating the design of the apparatus beyond the point of practicality, to circulate the water through a charcoal filter as it is done in an aquarium. The charcoal, therefore, was simply spread on the bottom; it was hoped that enough surface was exposed to the water for adequate adsorption. For each test 0.75 to 1.00 pound was used in a layer about 0.50 inch deep on the bottom. A new supply of bone charcoal was used for each test in order to insure that its adsorptive properties were not exhausted.

Table 5 shows that use of the buffer maintained the fish for 70 hours, whereas the fish lasted more than 90 hours in the charcoal treatment. The results seemed to indicate a slight advantage for the charcoal. The holding time was slightly increased, and the carbon dioxide content was lower. It appeared to have a greater stabilizing effect on pH; it also seemed to keep the water clearer by helping to settle the solid waste products that would otherwise have been suspended in the medium. The advantage of bone charcoal, as compared to dibasic sodium phosphate, may be greater for species of fish that are sensitive to hard water and to dissolved salts in it.

USE OF UREASE AND PERMUTIT

Urease and permutit were used to eliminate urea and ammonia from the system in order to determine whether this treatment would increase survival time of the fish. It was assumed that nitrogen compounds were the major constituents of the metabolic products: urea occurred in the greatest amount, and ammonia next. One-fourth gram of urease (in the form of jack bean meal) per liter of water was used to decompose urea, and permutit was added to absorb the resulting ammonia; thus treatment was applied to the greatest portion of the metabolic discharges.

In all the tests of this series (table 6), oxygen seemed to be the limiting factor. It seemed probable that urease was highly susceptible to decomposition, which explained the rapid utilization of oxygen by the bacterial action accompanying the decomposition process. The end point for each of the tests was reached at about 70 hours, with a resultant low oxygen content and high mortality of fish. Oppenheimer (1955) discussed in detail experiments performed with combinations of antibiotics as bacterial controls for the hatching of fish eggs. A similar treatment of the water with antibiotics may be suggested for further experimentation with urease to prevent bacterial decomposition.

USE OF ION-EXCHANGE RESINS

Portions of a cation-exchange resin and an anion-exchange resin were received from the Hawaii Marine Laboratory for

TABLE 6.-Tests in 8-liter bag using oxygen, charcoal, sodium amytal, urease, and permutit

Number of fish	Approximate size (cm.)	Weight (gm.)	Time (hrs.)	Oxygen (cc./l.)	Carbon dioxide (mg./l.)	pH	Nonprotein nitrogen (mg.%)	Remarks
18	4.5 - 8	75	72.0	0.66	33.55	7.5	2.3	Permutit 20 gm.
23	4.5 - 8	100	73.5	.82	34.27	7.6	2.7	Permutit 20 gm.
25	4.5 - 8	100	73.5	.00	28.87	6.9	2.3	Permutit 40 gm.
23	4.5 - 8	100	69.0	.74	38.83	7.1	1.6	Permutit 100 gm.
22	4.5 - 8	100	69.0	.90	39.30	7.5	2.2	Permutit 100 gm.

use in the experiments. About 400 grams of Tilapia mossambica was put in 4 liters of water in each of 2 aquaria that were constantly aerated to eliminate oxygen as the limiting factor. The cation-exchange resin was added to one aquarium, and the other was used as a control. Similarly, 150 grams of bluegill was treated with anion-exchange resin. Daily determinations of NPN content were made and tabulated in tables 7 and 8.

The results seemed to favor the cation-exchange resin. The treatment outlasted the control by 6 days and showed a low ammonia content.

For the anion-exchange test, the treatment aquarium was stopped a day before the control when approximately 50 percent of the fish were dead.

Experiments in holding bluegill with the resins were also performed with oxygen and charcoal in plastic bags. In order to facilitate the sampling of water while the experiment was in progress, the open end of each bag was tied around a glass-tubing stem that extended into the bag at one end and was attached to rubber tubing with a suction bulb on the other. Water to be sampled was drawn by this bulb through the stem and past the rubber-tubing area, where the required amount of water was taken with a hypodermic syringe.

As shown in table 9, this test ended with a premature loss of oxygen. The bag tied around the glass-tubing stem failed to give an airtight seal and consequently became deflated in a few hours. There were indications, however, that these resins--especially the cation-exchange resin--had some possibilities. The experiments with the cation-exchange resin should be pursued further.

SUMMARY and RECOMMENDATIONS

These tests were conducted to observe the effects--on the survival time of the fish in a sealed container--of increasing the oxygen supply and controlling the metabolic products in an attempt to devise a method to hold a maximum amount of fish for the longest time possible.

Oxygen supply was increased by replacing atmospheric air with pure oxygen and by introducing pure oxygen into the container under high pressure. For bluegill, at least, the high-pressure experiments proved unsuccessful; but the use of oxygen at one atmospheric pressure caused a definite improvement on survival time.

Phillips and Brockway (1954) demonstrated that starvation and lower temperature had a reducing effect on the metabolic rate of trout. This procedure of starvation and lower temperature was not tested in the bluegill experiments but would undoubtedly be a worthwhile consideration for shipping fish. Sodium amytal, however, was tested. It seemed to present a definite inducement for the reduction of the oxygen consumption rate. Other drugs like thiouracil (Osborn 1951) and anesthetics like urethane and chloretone had previously been used on salmonids, but none of these were tested.

Dibasic sodium phosphate was used as a buffer against pH changes as a result of metabolic discharges, and bone charcoal was used as an agent to purify the water.

TABLE 7.--Effect of cation exchange resin on accumulation of metabolic products of Tilapia mossambica, as measured by the accumulation of ammonia

Treatment	Accumulation of ammonia (mg.%) in number of days											Remarks
	1	2	3	4	5	6	7	8	9	10	11	
Control ----	----	----	----	----	5.17	----	----	----	----	----	----	Control.--399.5 grams of fish in 4 liters of water. All fish found dead on 5th day.
Resin, 195.5 grams	----	----	----	----	3.92	4.35	4.90	4.90	4.84	5.60	4.84	Resin.--400.2 grams of fish in 4 liters of water. One fish found dead on 6th day, trapped in cellophane bag. Experiment stopped at end of 11th day.

TABLE 8.--Effect of anion exchange resin on accumulation of metabolic products of bluegill sunfish, as measured by the accumulation of ammonia

Treatment	Accumulation of ammonia (mg.%) in number of days											Remarks
	1	2	3	4	5	6	7	8	9	10	11	
Control ----	1.00	3.03	5.06	----	9.46	11.15	15.77	14.52	----	----	----	Control.--149.8 grams of fish in 4 liters of water. Experiment was stopped on 8th day, when all fish appeared in a weakened condition.
Resin, 200 grams	1.08	4.03	3.03	----	4.86	7.60	7.88	-----	----	----	----	Resin.--150.1 grams of fish in 4 liters of water. Experiment was stopped on 7th day, when 19 fish were found dead.

TABLE 9.--Anion exchange resin and cation exchange resin with oxygen and charcoal

Resin	Time (hrs.)	Weight of fish (gm.)	Oxygen (cc./l.)	pH	Nonprotein nitrogen (mg.%)	Remarks
Anion exchange						
Test 1 -----	0	300	11.17	8.05	----	Only 1 fish found alive at 48 hours. Leaky bag.
	24	---	-----	8.05	0.93	
	48	---	1.42	7.85	2.70	
Test 2 -----	0	200	12.05	7.80	----	All fish found dead at 48 hours. Leaky bag.
	24	---	-----	7.60	1.50	
	48	---	.92	7.40	4.15	
	72	---	-----	----	----	
Test 3 -----	0	200	12.41	7.75	----	Almost half the amount of fish found dead at 48 hours. Leaky bag.
	24	---	-----	7.65	1.62	
	48	---	1.67	7.65	2.60	
Cation exchange						
Test 1 -----	0	300	10.97	7.50	----	All fish found dead by 72 hours. Leaky bag.
	24	---	-----	7.55	1.80	
	48	---	-----	8.90	2.00	
	72	---	.68	8.30	3.03	
Test 2 -----	0	200	12.11	6.80	----	Half the amount of fish found dead at the end of 48 hours.
	24	---	-----	7.95	0.57	
	48	---	-----	7.65	3.18	
	72	---	-----	----	----	

Results showed a slight advantage to the use of charcoal rather than the salt buffer.

Urease, permutit, and ion-exchange resins were tested to observe the effects that the elimination of metabolic products from the sealed system might have on survival time. The tests all ended with a lack of oxygen. The cation-exchange resin seemed to offer possibilities, and it is recommended that this be tested further.

On the basis of the foregoing experiments, the following recommendations are made for a fish-shipping procedure:

1. Use of pure oxygen in a plastic bag such as is commonly employed in the exotic-fish trade. One atmosphere of oxygen forming about 75 percent of the container size; the remaining 25 percent consisting of water, fish, and other constituents.

2. A layer of bone charcoal at the bottom; about 1 pound per 4 liters of water.

3. A concentration of not more than 1 gram of fish to 13 cubic centimeters of water. A lesser concentration, perhaps 1 gram to 20 cubic centimeters of water, is recommended to allow for a safety factor.

4. About 1 grain of sodium amytal to 4 liters of water.

5. It is also suggested that the fish be starved, commencing 1 day before shipment, to lessen metabolic discharges.

It is highly recommended that a trial shipment pack be made each time a new species of fish is considered for shipment. Different species of fish have various degrees of tolerance for the different treatments mentioned. For example, the

dose of sodium amytal used in the bluegill experiments was successfully employed with shipments of Tilapia mossambica. When used on Stolephorus purpureus, however, this same drug was found to be lethal and hence was adopted for a while to euthanize the fish. It appears, therefore, that modifications of the method might be necessary for each species of fish.

Several shipments of the bluegill and Tilapia mossambica by this scheme have been made successfully, and it is believed that this method--using the plastic bag in a paper carton--is completely adequate for more than 70 hours. It readily fulfills the conditions for an ideal shipping container, being durable, light, simple, and inexpensive. Regarding the advantages of plastic bags as opposed to metal cans, Miller (1956) wrote:

> ...they prevent injury to the fish bumping against the container walls, do not rust, and take up little room prior to their use in the field ... Equalization of water temperatures between the plastic bag and the aquarium intended for the fish is readily accomplished by floating the bag in the aquarium.

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In the years 1947 through 1952, the Coleman (California) Hatchery of the U. S. Fish and Wildlife Service made a minimum average contribution of 18.91 percent to the catch of the gill-net fishery for Oncorhynchus tshawytscha.

THE NUTRITION OF TROUT
V. INGREDIENTS FOR TROUT DIETS

Arthur M. Phillips, Jr.
Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, Cortland, New York
and
George C. Balzer, Jr.
Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, Boston, Massachusetts

THE NUTRITIONAL REQUIREMENTS FOR HATCHERY TROUT are satisfied through the food that is fed. The efficiency of a diet is a direct reflection of the skill and knowledge of the fish-culturist. In a discussion of the dietary ingredients that may be used to satisfy the needs of trout, three questions arise: Why is food necessary? what ingredients should be used? and, how is the efficiency of a hatchery diet measured? In this paper these questions are discussed separately.

WHY IS FOOD NECESSARY?

Food supplies the energy and raw material that are necessary to carry on the processes of life from the time of conception until death. Only that material which is absorbed into the body through the digestive tract or gills may be considered food, for only after absorption is the material available to the body. After absorption the nutrients are distributed throughout the body to serve many purposes.

The utilization of food in the animal body is described by the word "metabolism." Metabolism includes all of the chemical processes that food undergoes to satisfy the requirements of the living body (growth, energy, reproduction, etc.). Metabolism occurs every instant of life, but the amount of metabolism varies with the activities of the body. Metabolism is at a low level during sleep and at a high level during work or play. Food is supplied to the body for the sole purpose of allowing normal metabolism to occur. Hunger is a signal to the body that the materials for metabolism have been reduced, and that it is time for the supply to be replenished.

Metabolism in the animal body may be classified as constructive metabolism (anabolism) or as destructive metabolism (catabolism). Anabolism is the construction of materials useful to the body. The end products of anabolism are new tissues (growth and repair), enzymes for digestion, red blood cells, reproductive products, and many more. Catabolism is the burning of carbohydrates, fat, and protein in the body to produce energy and represents a loss to the animal body because the food is not utilized directly to produce body substances. For the most part, the end products of catabolism are carbon dioxide, water, and nitrogen, which leave the body through the lungs and/or urinary tract, and energy, which is lost to the body through radiation. Catabolic processes furnish the energy that is used for all body processes (growing, swimming, seeing, reproducing, etc.). Catabolism occurs during periods of starvation, as no life can be maintained without energy and catabolism is the source of energy for the body. Catabolism always accompanies anabolism, for energy is necessary

for the conversion of raw foods into body substances.

Bodily activities that either increase or decrease the rate of metabolic processes alter the dietary requirement. Heavy work increases the energy requirement of the body, and there must be an increase in the consumption of energy foods to satisfy the need or body tissues will be burned to meet the increased demand for energy. During reproduction the amount of protein, minerals, and vitamins must be increased to meet the growth requirements of the developing young, and the amounts of fats and carbohydrates must be increased to provide energy for the body processes within the developing young. If the needs of the embryo are not met by the diet, the materials will be removed from the mother's body.

A basic amount of energy is required to maintain life even when the animal is at complete rest. This is known as the basal metabolism. Because metabolism is a chemical process, the rate of basal metabolism varies with body temperature. The body temperature of warm-blooded animals is relatively constant for a given species, and the rate of basal metabolism is also relatively constant. Under certain conditions, such as extreme cold, the basal metabolic rate is altered. The rate of metabolism in extreme cold is increased by the involuntary act of shivering, which provides additional energy or heat to maintain normal body temperature. During illness with accompanying fever, the basal metabolism of the body is increased by 10 percent for each degree of rise in body temperature.

The body temperature of cold-blooded animals is almost identical with the temperature of the environment. There is a particular basal metabolic rate for each temperature normal to each particular species of cold-blooded animal. If body temperature influences the basal metabolism of cold-blooded animals to the extent that it does warm-blooded animals, there must be a tremendous range of normal metabolic rates of cold-blooded animals with changes in environmental temperatures. The normal body temperature of trout, for example, may be from 32° to 70° F. The basal metabolic rate would be extremely high at 70° F., in comparison to the rate at 32° F. It is safe to assume that more food is needed to meet the basic energy requirement of fish at a higher water temperature.

Diet composition has an effect upon the metabolic rate of an animal. Feeding to higher animals an amount of protein in excess of the protein requirement of the body causes the formation of fat from the excess protein. Sixteen percent of protein is nitrogen, which is wasted when fat is formed. The metabolic rate of the animal increases to provide energy to eliminate the excessive nitrogen (ammonia). Similarly, feeding excessive amounts of minerals (for example, salt) may cause an increase in metabolism for the purpose of providing energy to excrete the excessive minerals and prevent toxic accumulations in the blood and tissues.

Nutritional deficiencies occur more rapidly in periods of increased metabolism. Nutritional deficiencies of this nature do not occur frequently in warm-blooded animals, except during periods of prolonged illness. However, in cold-blooded animals increased metabolism caused by increased water temperatures often results in nutritional disorders. Thus, vitamin deficiencies occur more quickly in trout living in warm water than in those living in cold water. It is often impossible to rear trout during the summer on diets that were satisfactory during the winter.

An animal's age is a factor governing metabolism. The metabolic rate of young, rapidly growing animals is higher than that of adults that have ceased to grow. Trout fingerlings have a higher rate of metabolism than larger trout. The feeding tables in common use in trout hatcheries are based on fish size and water temperature. These feeding tables are actually fuel tables of metabolism.

Many diseases of trout and of higher animals alter the metabolism of the body. For example, furunculosis and kidney disease of trout destroy the kidney, which is the organ for excretion of some of the end

products of catabolism. The destruction of this organ prevents normal excretion, eventually disrupting the entire metabolic pattern of the fish, and death then occurs. Any disease or nutritional deficiency that affects any single phase of metabolism eventually affects all phases of the body's metabolism, as each separate phase of metabolism is dependent on every other phase.

Because increased activity of the body increases the metabolic activity of the animal, it is safe to assume that trout living in fast waters have a higher metabolic activity than those living in ponds, for the trout expend more energy to maintain themselves in the current. Trout living in fast waters would require more energy foods (fats and carbohydrates) than those living in the calmer environment of ponds.

It has been shown experimentally that the chemical content of waters affects the metabolic activity of trout living therein. For example, waters low in calcium upset the osmotic regulation of the trout's body. The metabolic rate of the fish increases because of an active effort by the trout to prevent the low calcium content of the water from causing osmotic changes in the body.

WHAT INGREDIENTS SHOULD BE USED?

The sole requirement of an animal's diet is that it must contain all of the ingredients required to satisfy all of the metabolic needs of the body. If the nutritional requirements--which are actually the essentials of metabolism--of an animal are known, a satisfactory diet may be selected from the known chemical composition of various ingredients. If the nutritional requirements are incompletely known, actual testing (feeding trials) of a diet mixture is necessary. Unfortunately, the design of hatchery diets for trout, for the most part, must be achieved through feeding trials. The only satisfactory way to determine the efficiency of new trout diets is to test the diets under experimental conditions. Of course, chemical analyses of the feeds in a diet will determine whether the diet design contains all of the elements that previous experiments have established as essential for trout.

Trout diets usually consist of either meat or a mixture of meat and dry plant and animal concentrates. The dry concentrates are not used until the trout reach a size of 1.5 inches. Meat must be fed to trout of all sizes to supply unknown factors that are required for normal growth and health. The dry concentrates are added to the diet of the larger trout to reduce the cost of the diet and to give a balance to the mixture in the form of minerals, protein, and carbohydrate.

Recently pelleted fish foods have come into wide use in trout hatcheries, but--as far as is now known--supplemental fresh meat must be fed regularly. It is almost certain that, within a short time, pellets that can be fed without fresh meat supplements will be developed.

Dietary ingredients are selected on the basis of nutritional value, availability of the product, and cost of the ingredient.

The nutritional value of an ingredient is determined from the chemical composition of the product as compared to known dietary requirements, or from trial-and-error experiments in which the ingredient has been tested and proved satisfactory. Some products are unfit for trout diets because of their consistency, which may be a function of the method of manufacture. Manufacturing processes may alter the efficiency of ingredients by reducing their digestibility or by changing the chemical form of the food. Some ingredients are used as sources of protein (for example, white fish meal). Other foods may be added to the diet for their vitamin content (dried brewer's yeast) or for their growth-promoting effect (cod-liver oil). Tables 1 and 2 list the chemical composition of a number of foods that have been used in trout diets.

The availability of a product is important in any decision to include that product in a diet for hatchery trout. The best food obtainable is of little value if the commercial supply is limited. There are several products (for example, salmon

TABLE 1.--The chemical composition of some foods for hatchery trout

Food	Percent					
	Protein	Fat	Carbohydrate	Ash	Fiber	Water
Fresh meats						
Heart, beef	14.8	24.7	0.9	0.9	----	53.2
Kidney, beef	13.7	1.9	.4	1.0	----	74.0
Liver						
Beef	20.2	3.1	2.5	1.3	----	72.3
Pork	21.3	4.5	1.4	1.4	----	72.8
Sheep	23.1	9.0	5.0	1.7	----	61.2
Lungs, beef	16.4	2.8	----	1.0	----	79.7
Spleen						
Beef	18.0	2.3	----	1.4	----	75.2
Pork	17.0	1.9	----	1.4	----	78.0
Fresh fish						
Alewife	10.0	2.4	----	0.8	----	72.0
Carp	10.0	15.0	----	.5	----	73.0
Herring	11.2	3.9	----	1.6	----	72.0
Whiting	18.8	4.0	----	5.4	1.7	71.0
Animal meals						
Buttermilk, dried	33.8	5.6	41.9	10.5	0.3	7.8
Liver, dried	67.2	14.6	2.4	7.5	1.9	10.0
Meat	55.0	12.0	1.2	25.0	2.2	10.0
Skim milk, dried	34.8	.9	50.1	8.0	----	6.2
Plant meals						
BY-100	25.0	0.5	40.0	12.0	5.0	8.0
Cottonseed	38.0	8.0	39.9	6.4	10.5	10.0
Kelp	5.6	.7	43.7	33.2	7.5	10.0
Red dog flour	16.8	4.1	65.5	2.5	2.4	10.0
Soybean (expeller)	49.9	6.2	26.4	5.5	5.1	10.0
Solubles, distiller's	25.0	5.0	48.0	7.5	4.0	----
Wheat middlings	17.8	5.0	62.8	3.7	4.4	10.0
Wheat shorts	17.4	4.9	62.8	4.4	6.2	10.0
Fish meals						
Menhaden	62.0	7.0	0.8	21.0	2.4	10.0
Salmon	55.0	----	----	----	----	10.0
Sardine	64.5	9.8	3.8	15.2	.2	10.0
White fish	54.5	8.8	4.6	22.0	1.0	10.5
White fish	68.0	2.0	3.6	19.0	.7	10.0
Red fish	57.0	6.0	----	26.0	1.0	10.0

meal) that have proved useful in rearing trout on an experimental basis--but are not used in trout diets because of the limited supply.

The cost of an ingredient determines whether it is economical to include the product in a trout diet. The cost must not be measured in terms of purchase price alone but rather in terms of the cost to produce 1 pound of trout (conversion times the cost of the food per pound). The use of an expensive ingredient is not justified if a less expensive one produces equal results, and the use of a cheap ingredient is not justified if a more expensive product is superior in terms of the cost to produce 1 pound of fish flesh.

TABLE 2.--The vitamin content of some foods for hatchery trout

Food	Milligrams per 100 grams of food								
	Thiamine B_1	Pyridoxine B_6	Riboflavin G	Pantothenic acid	Biotin	Folic acid	Niacin	Choline	B_{12}
Fresh meats									
Heart, beef	0.61	0.24	1.76	1.80	0.008	0.11	7.0	170	0.017
Kidney, beef	.51	.44	.20	3.70	.022	----	10.0	360	.017
Liver									
Beef	.27	.85	4.05	5.53	.131	.29	17.5	320	.105
Pork	.52	.33	5.40	5.00	.044	----	19.0	470	.043
Sheep	.14	.37	5.20	5.34	-----	----	15.0	---	-----
Lungs, beef	.20	.07	.49	1.80	.003	----	6.2	---	.002
Spleen									
Beef	.16	.12	.45	1.10	.011	.15	7.5	---	.003
Pork	.24	.12	.76	1.60	.004	.12	4.3	208	-----
Fresh fish									
Alewife	-----	----	-----	-----	-----	----	---	---	-----
Carp	0.01	----	0.02	-----	-----	----	0.9	---	-----
Herring	.12	----	.31	-----	-----	----	3.0	---	-----
Whiting	-----	----	-----	-----	-----	----	---	---	-----
Animal meals									
Buttermilk, dried	0.28	----	3.30	4.40	-----	----	1.7	111	-----
Liver, dried	1.20	----	10.20	15.40	-----	----	98.3	---	-----
Meal	.12	----	.60	.80	-----	----	6.8	189	-----
Skim milk, dried	.35	0.45	2.05	3.30	0.039	0.03	1.1	160	-----
Plant meals									
BY-100	0.32	1.06	10.00	48.00	0.15	0.11	22.0	52	0.010
Cottonseed	1.30	.69	.40	1.14	.05	.07	2.3	266	-----
Kelp	-----	----	-----	-----	----	----	----	---	-----
Red dog flour	2.18	----	.24	1.40	----	----	5.5	100	-----
Soybean (expeller)	1.35	.35	.33	2.00	----	.33	3.9	244	-----
Solubles, distiller's	.55	.90	1.10	2.20	.03	.11	12.1	550	-----
Wheat middlings	1.32	.73	.31	1.20	.06	.07	4.3	100	-----
Wheat shorts	1.70	----	.26	1.10	----	.08	9.5	100	-----
Yeast, brewer's	11.00	3.00	4.40	11.00	2.50	2.00	47.0	440	0.001
Fish meals									
Menhaden	-----	----	0.46	0.89	----	----	5.5	311	-----
Salmon	-----	----	-----	-----	----	----	----	---	-----
Sardine	-----	----	.70	.28	----	----	6.7	289	-----
White fish	0.09	0.21	.96	1.22	0.04	0.05	6.7	155	-----
Red fish	-----	----	.80	.66	----	.03	4.1	311	-----

Food ingredients may be grouped into the following classes: (1) fresh meats, (2) fresh fish, (3) plant concentrates, (4) animal concentrates, and (5) dietary supplements.

1. Fresh meats provide unknown elements that are essential for the prevention of anemia in trout, and many of these products are excellent sources of essential vitamins. At present some source of fresh meat must be provided in all hatchery feeding programs. In addition, some of the fresh meats (spleens), when combined with salt, form a rubberlike

mass that resists disintegration when it is placed in the water, thus assuring more complete consumption by the trout.

2. Fresh fish have been widely used in trout diets but must be fed with caution. Fresh fish may cause a thiamine deficiency when fed to trout, resulting in high mortalities. Among the fish species that are known to cause a thiamine deficiency are whitefish, bullheads, carp, goldfish, suckers, buckeye shiners, salt-water herring, and creek chubs. Cooking the fish before feeding it to the trout eliminates the trouble but adds to the labor cost of food preparation. The inclusion of fish that will not cause a thiamine deficiency in the diet of trout usually results in a high rate of conversion of food into fish flesh. The low cost of the fish product is not an advantage, as the cost of production in terms of fish flesh produced is usually higher than the cost of production when the other available hatchery diets are used. The best practice is to eliminate fresh fish from the diet of hatchery trout.

3. Plant concentrates are the cheapest of the ingredients that are commonly used in trout diets. These products are mainly a source of carbohydrate, although many of them contain a fairly high percentage of protein. As the carbohydrate in plant products is mostly in the form of starch (which is poorly digested by trout), these products provide bulk and act as "fillers" in the diet. The use of plant concentrates results in a cheaper diet that does not interfere with rapid growth if the balance of the diet is properly compounded. Many of the plant products are excellent sources of essential vitamins and may be used to fortify the diet of trout.

4. Animal concentrates are excellent sources of protein for trout growth. All of these products are artificially dehydrated, and the method of manufacture determines their value in hatchery diets. In general, products that are dried in vacuum, under low heat, are superior to those dried in air, under high heat. The majority of the animal concentrates are poor sources of vitamins.

5. Dietary supplements are materials which provide specific essentials or perform a specific function in the food of animals. In fish hatcheries there is a tendency to utilize many of the commercially available supplements that have been developed for the diets of higher animals. There is little experimental justification for the inclusion of these products in trout-hatchery diets. Only three supplements--salt, dried brewer's yeast, and cod-liver oil--have produced results that justify the additional expense. The antibiotics that have proved so valuable in the husbandry of higher animals have failed in trout diets as promoters of growth or reducers of conversion values. None of the tested commercial vitamin supplements (except dried brewer's yeast) have justified their use in trout diets.

It is not feasible to suggest that one specific diet mixture should be fed at all trout hatcheries. The cost of ingredients and their availability vary from one section of the country to another, and a good mixture for one area may be too expensive for another. A number of diet mixtures that have been developed produce satisfactory results when fed to trout. Table 3 lists several of these mixtures. Changes in these diets are possible, and many different combinations of the listed ingredients would be satisfactory. The compounding of a trout-hatchery diet should be based on the known nutritional requirements of the fish (sections II, III, and IV of this series), and this diet should be fed by the accepted methods (section I of this series). Any new mixture that has not been tested should be evaluated under experimental conditions before it is put to use in the hatchery.

HOW IS THE EFFICIENCY OF A DIET MEASURED?

The determination of the efficiency of a hatchery diet is based on the results obtained. This does not mean that testing must be conducted in a laboratory, as any hatchery can test new products and diet mixtures if the testing is carefully controlled. All precautions must be taken to assure a completely unbiased evaluation of the diet.

TABLE 3.--A few suggested diet mixtures for hatchery trout

Ingredient	Mixtures for mush, blower, and cement-mixer feeds [1]								Pellet mixtures [1]		
	Cortland: No. 6	6a	6b	6c	6d	6e	6f	6g	Cortland	Minneapolis	New Jersey
Dried skim milk	12	------	------	------	------	------	------	------	7	11	8
White fish meal	12	12	12	12	12	12	12	------	40	16	25
Cottonseed meal	12	12	12	12	12	12	12	12	15	24	15
Wheat flour middlings	12	12	-----	12	6	12	12	12	25	24	20
Distiller's solubles	-----	12	-----	------	12	12	12	12	------	11	15
Dried buttermilk	-----	------	-----	------	6	------	------	------	------	------	------
Red dog flour	-----	------	12	------	------	------	------	------	------	------	------
Menhaden fish meal	-----	------	12	------	------	------	------	12	------	------	------
BY-100	-----	------	------	12	------	------	------	------	------	------	------
Cod-liver oil	-----	------	------	------	------	3	3	3	3	------	[2] 3
Dried brewer's yeast	-----	------	------	------	------	5	------	5	10	10	10
Salt	2	2	2	2	2	2	2	2	------	4	4
Pork spleen	30	------	------	------	------	------	------	------	------	------	------
Beef spleen	-----	30	30	30	30	42	27	42	------	------	------
Beef liver	20	20	20	20	20	------	20	------	------	------	------

[1] Amounts of ingredients are in percentage.
[2] 1.5 percent vitamin A and D powder and 1.5 percent of stabilized fat are substituted for cod-liver oil.

The usual measures of the efficiency of a hatchery diet are growth of the fish, conversion of the food into fish flesh, mortality of the fish, and the cost to produce 1 pound of fish flesh. Under some experimental conditions the effect of the diet on the chemistry of the trout's body is studied. Of these measures, all but the chemistry of the body may be studied satisfactorily in the ordinary production hatchery. The first four measures mentioned here are usually sufficient to establish the value of diet mixtures.

It is essential that all experimental groups of trout in a feeding trial receive identical treatment. The fish under experiment should be of the same size and from the same source of eggs. The testing units, ponds or troughs, should be stocked at a uniform rate of fish per cubic foot of water, and the same flow of water should be passed through each unit. The food fed to the fish must be accurately weighed, one container being used for each experimental group. For most experiments, each group should be fed the same amount of food in terms of percentage of the body weight. If the amount fed is the variable, this must be considered in judging the final results. The experimental groups of fish should receive priority over all other hatchery activities, and it is preferable to assign one reliable man to care for the fish.

All diets should be tested at least in duplicate, preferably in triplicate. Replication of the diets allows normal variation and produces greater accuracy for judging the diets. There must always be a control, which is usually the standard hatchery diet. The experimental diets are compared to the control diet. The control diet must be fed concurrently and under the same experimental conditions as the diets under test.

The experimental trout should be weighed, and adjustments of the food allowance made, at biweekly intervals. Accurate scales must be used. The entire groups of fish must be weighed. This eliminates the error that is an inherent part of sample-counting. If the weights of fish exceed the capacity of the holding units during the period of experimentation, trout may be removed. The fish to be removed are selected at random by crowding them into a relatively small area and taking them out while they are in motion. While the fish are being transferred, the addition of water to the weighing container must be avoided. One cubic centimeter of water weighs 1 gram, and it does not take many cubic centimeters of water to invalidate the weighing.

The numbers of fish per experimental unit are usually established by sample-counting the fish and relating these values to the total weight in the unit. As all judgments (except mortality) are based on the total weight of fish, this inaccuracy of numbers is relatively unimportant.

The experiments must be run for a period of time sufficient to establish valid conclusions. Usually, in warmer water (above 50° F.), with small fingerling trout, the period of experimentation is 16 to 20 weeks. In colder water (below 50° F.), the experiments may have to run for 6 months or more. In some types of diet experimentation it is desirable to continue the experiments throughout an entire growing season, regardless of the size of the fish or the temperature of the water.

For hatchery experimentation, the hatchery management chart may be used to record the data (Deuel et al., 1952). From the hatchery management charts, those diets producing sufficiently large deviations (growth, mortality, conversion, and cost to produce a pound of fish) from the control may be considered better than or poorer than the control, depending on the direction of the deviations. The duplicate or triplicate troughs should agree in results produced, or the significance of differences will not be valid when compared to the control. It is difficult to state the actual difference that must occur for significance. In general, the difference must be consistent and should not be less than 10 to 15 percent for growth, less than twice for mortality, and not less than 0.5 pound for conversion. During periods of rapid growth, however, the difference may have to be greater than 10 to 15 percent for growth. Judgment must be used

in reaching conclusions. For precise measurement of differences, elaborate mathematical procedures are used. These methods are not suitable for application to hatchery procedures but are used under laboratory conditions.

Any major change in diets for trout hatcheries should be attempted first on an experimental basis. At present there is no other basis for knowing whether untried products will be satisfactory for rearing trout.

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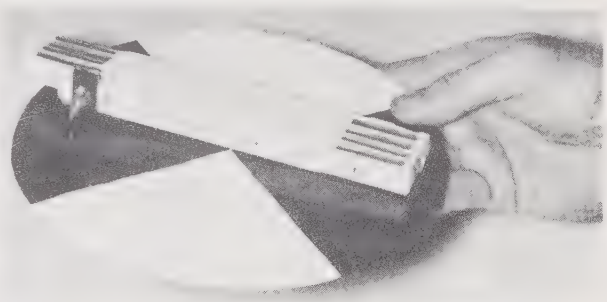
TWO MODIFICATIONS OF THE SECCHI DISK

For years fishery workers have used the Secchi disk to measure the turbidity of water. Recently, however, C. R. Walker and R. M. Burress, employees of the Fisheries Section of the Missouri Conservation Commission, have completed a series of tests of several modifications of the Secchi disk. On the basis of this work, Messrs. Walker and Burress have described two modifications which have proved especially helpful in farm-pond investigations.

One very successful modification has involved the attachment of a sturdy yardstick to a Secchi disk by means of a strap hinge. The Secchi disk is made of heavy sheet metal, 20 centimeters in diameter, with holes drilled to permit attachment of the hinge with small, brass stove bolts. The disk is painted after the hinge is attached. This modification of the Secchi disk can be carried conveniently and without damage to the instrument. Transparency measurements greater than 3 feet are made by attaching a second rule as an extension with another strap hinge.

The second modification recommended makes use of a 6-foot folding carpentry or masonry rule (see photograph). The metal rule has proved most durable for this purpose. The disk is attached to the rule by two metal corner straps secured by brass stove bolts. The tension and position of the rule are easily regulated by adjusting the wing nut and bolt by which the end of the rule is secured to the disk. This modification is more compact than the one involving the yardstick, although less durable.

(Photograph courtesy of C. A. Purkett)



"In conclusion . . . the ovarian ripening cycle in S. fontinalis does not depend to any great extent on the age or size of the fish, but mainly on the amount of food assimilated previous to spawning." --V. D. Vladykov: Fecundity of wild speckled trout (Salvelinus fontinalis) in Quebec Lakes. Jour. Fish. Res. Bd. Canada 13 (6): 828.

THE CONTROL OF SQUAWFISH BY USE OF DYNAMITE, SPOT TREATMENT, AND REDUCTION OF LAKE LEVELS

Paul Jeppson
Idaho Fish and Game Department
Sagle, Idaho

THE COLUMBIA RIVER SQUAWFISH, Ptychocheilus oregonensis (Richardson), though known to be an important predator on game fishes (Ricker 1941, Munro 1934), has received little attention with regard to control measures. Godfrey (1955), in a study of the food habits of squawfish in three British Columbia lakes, found that 17.5 to 84.2 percent of the volume of the stomach contents of squawfish consisted of fish--mainly stickleback, young salmon, and young trout.

The food habits of squawfish and trout from streams and lakes near St. Maries, Idaho, were studied by Vaughan.[1/] It was concluded that the feeding habits of squawfish and trout were quite similar. Fish made up 2.3, 3.7, 9.2, and 27.3 percent, respectively, of the stomach contents of 4- to 9-inch, 9- to 11-inch, 11- to 15-inch, and 15- to 23-inch squawfish.

In northern Idaho, the changed watershed conditions that have evolved with settlement of the region have generally resulted in warmer waters, reduced bank cover, siltation, and intermittent flows in streams. Suckers and native cyprinids, such as squawfish, peanose, and longnose dace, are now the dominant fishes in some waters. Throughout the Northwest, greater abundance of squawfish has been accompanied by an increase in its range (Lindsey 1956).

With the evident increase in nongame fish in areas which have been productive of trout, various control measures have been adopted. Small lakes and their drainage basins have been successfully treated with Fish Tox and rotenone to eradicate undesirable fish populations and have been restocked with trout. Tench and suckers have been cropped with hoop nets, runs of stream-spawning suckers eradicated with rotenone, and spawning sites of the squawfish dynamited and treated with fish eradicants.

Attempts to control squawfish numbers in the larger lakes and streams of northern Idaho have met with varying degrees of success. Provision of an adequate control appears to depend upon understanding the ecology of the squawfish in each water and attacking these fish during the spawning and developmental period. Sigler (1955) suggested such an approach with regard to carp control. Shields, through a study of water temperatures and depths associated with carp spawning, developed a control method in Missouri River mainstem impoundments in South Dakota.[2/]

By means of trial-and-error testing of nets, traps, and fish eradicants in northern Idaho waters, it was determined that the use of dynamite was a relatively

1/ Vaughan, T. M. Survey of certain fisheries problems in vicinity of St. Maries, Idaho. Idaho Department of Fish and Game, Boise. 9 pp., mimeo. 1947.

2/ Shields, J. T. Carp control through water drawdowns, Fort Randall Reservoir, South Dakota. Dingell-Johnson Project, F-1-R-5, supplement. South Dakota Department of Game, Fish and Parks, Pierre. 10 pp., mimeo. 1956.

efficient method of dispersing or eradicating the spawning schools of squawfish. In squawfish-control work, ditching dynamite (50 or 60 percent gelatin) was preferred because it sank and was resistant to moisture. Hubbs and Rechnitzer (1952) indicated lethal effects on fish from dynamite explosions at peak pressures of 40 to 70 pounds per square inch; that damage to fish varied with the "type and amplitude of the pressure pulse, the kind of bottom, and the structure and size of the fish"; that "hemorrhaging, burst air bladders, and general disruption of the viscera" were among the causes of fish mortality; that maximum pressures did not increase in proportion to the weight of the charge but varied as the "one-third power of the weight of the charge,"--for instance, "a one-pound charge produces one-half the pressure that an eight-pound charge does." They also reported that "five-pound charges damaged fish at distances of about 65 feet" in salt water, and that "the effect of underwater explosions of such substances as dynamite is often intensified at the surface, where the positive compression wave is reflected as a rarefaction wave" (pressure less than atmospheric).

Methods

A project designed to reduce the number of squawfish in 3,200-acre Hayden Lake was begun in 1953. Gill nets, their bar-mesh sizes ranging from 1.5 to 2.5 inches, were used at various sites in the lake over an 8-week period beginning in mid-May. Gill-net indices (the catch of squawfish per 100 feet of net per 24-hour period) indicated, as the spawning time approached, that squawfish were congregating along a 1-mile stretch of rocky shoal, where spawning schools were subsequently located. The size and composition of the squawfish schools made the use of dynamite practical. Fish Tox and rotenone were used but tended to disperse the adult squawfish with little observed mortality, although small young-of-the-year and yearling squawfish were susceptible to the treatment. Examination of the gonads of squawfish that were taken in gill nets indicated that spawning began about mid-June. After the dates and depths of the squawfish spawning had been determined, the sites were revisited to determine the length of the incubation period and the effects of a slowly receding water level upon eggs. After the hatching of eggs, Fish Tox was applied to kill squawfish fry.

Spawning

Squawfish spawning in Hayden Lake began when the surface waters had warmed to about 60° F. During the years 1953-56, squawfish spawning was noted only along about 1 mile of shoreline in an area of coarse, wave-washed rubble at depths of 2 to 12 inches (figure 1). The angular rubble was from 1 to 8 inches wide. Squawfish eggs were deposited in masses among the rocks, which provided protective cover and permitted circulation by wave action. Spawning was observed to occur on calm days only. Spawning schools were easily located because of the activity of many fish in shallow water. Egg masses could be observed at these sites (figure 2).

In 800-acre Cocolalla Lake, spawning took place in areas where the water was less than 1 foot deep over cobbles ranging from 2 to 10 inches in diameter.

In Hayden Lake, squawfish were estimated to make up about 10 percent of the number of fish in the lake, as determined from experimental gill-net sets in December 1953. Squawfish made up 88 percent of the catch of 1,227 fish taken by the selective use of gill nets during that year. In Cocolalla Lake, squawfish formed 26 percent of the catch in experimental gill nets during September 1956. Observations at northern Idaho lakes which have been treated with fish toxicants have indicated a relationship between the abundance of squawfish and the type and extent of suitable spawning shoal.

Squawfish eggs are gelatinous and slightly adhesive, sticking together in mats or spread upon rocks. Four 16- to 20.5-inch sexually ripe squawfish from Hayden Lake yielded 37,000 to 83,000 eggs per fish. Eggs were small, having

FIGURE 1.--Spawning squawfish may be seen as a turbulence along the water's edge. The backs of squawfish show above the water's surface, as these fish deposit eggs in very shallow water, where they are vulnerable to the slowly receding water levels.

(Photographs courtesy of the author)

an average diameter of 0.065 inch and numbering 250,000 to the quart. Eggs hatched in 7 to 8 days at the spawning sites in water temperatures ranging from 60° to 68° F.

Effects of Reduced Water Level on Eggs

The surface of Hayden Lake usually reaches an annual maximum level during the third week in May. During June and July the lake level recedes about 3 feet at an average rate of about 4 inches a week. Reduction of lake level, although slight, has been observed to result in mortality of squawfish eggs. During rainy weather, eggs remaining or left above the water level were observed to remain alive. Dry weather conditions caused their death.

Age and Maturity

At spawning time, male squawfish become darker and breeding tubercles form on the head and back. Male squawfish differ externally from females by a greater protrusion of the genital papilla. Squawfish in northern Idaho waters generally do not mature until their fourth or fifth year of life. A few males mature at 3 years. The majority of the spawning squawfish have been in age groups IV to VI. Male squawfish taken in gill nets at Hayden Lake averaged 16.2 inches in length and 1.66 pounds in weight. Female squawfish averaged 18.2 inches and 3.1 pounds. The largest squawfish observed was a 13-year-old, 26.5-inch, 9-pound female.

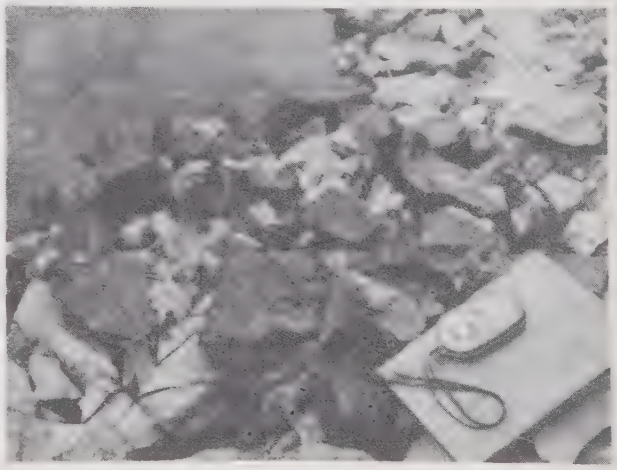


FIGURE 2.--Squawfish eggs excavated from the spawning site at the edge of the water. (The eggs were removed from the water so they would be visible in the photograph.)

Summary and Conclusions

1. Provision of an adequate control of squawfish appeared to depend upon understanding the ecology of squawfish in each body of water and attacking the fish in the spawning and incubation period. Dynamite was used in northern Idaho waters to eradicate spawning squawfish; newly hatched fry were eradicated by partial treatment with Fish Tox and rotenone.

2. Observations in lakes indicated a relationship between the abundance of squawfish and the type and extent of the spawning shoal.

3. During the period of study from 1953 to 1956, squawfish were observed to congregate each year along about 1 mile of shoreline in Hayden Lake. Spawning occurred in this area over coarse, wave-washed rubble at depths of less than 1 foot. The period of spawning extended from mid-June to mid-July in water temperatures ranging from 58° to 68° F.

4. The incubation period of squawfish eggs at water temperatures of 60° to 68° F. was 7 to 8 days.

5. Slight reduction in lake level was observed to cause mortality of squawfish eggs in Hayden Lake.

6. Observations at northern Idaho lakes supported the conclusion that lowering lake levels at a rate of 2 inches per day after the surface temperature warms to 60° F. will destroy virtually all squawfish spawn. Total drawdown would approximate 5 feet.

Acknowledgments

Appreciation is expressed to the following employees of the Idaho Fish and Game Department: Messrs. Forrest Hauck and James C. Simpson, for their editorial suggestions; and Mr. Charles Whitt, for age determinations of squawfish. Mr. R. M. (Pete) Williams of the Hayden Lake Fish and Game Association provided assistance in the field.

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Among our Great Lakes, Lake Erie is the only one that has a bottom above sea level. The bottom of Lake Ontario is approximately 269 feet below sea level; Lake Huron's, about 278 feet below sea level; Lake Michigan's, nearly 300 feet below sea level; and Lake Superior's lies deepest, being some 400 feet below sea level.

THE CORTLAND, NEW YORK, FISHERY STATION: A SUMMARY OF TWENTY-FIVE YEARS' WORK

This summary of an outstanding record of achievement has been prepared in recognition of the 25th anniversary of the establishment of the laboratory at the Cortland, New York, Fishery Station.--The EDITORS.

THE DEPRESSION, THE CLOSING OF THE BANKS, AND THE REPEAL OF PROHIBITION--these were major topics of conversation throughout this country a quarter of a century ago. In the Finger Lakes region of New York State, however, many people were talking about the announcement of a cooperative program for a laboratory-fish hatchery established about 6 miles from a small town known as Cortland.

Two years earlier, in 1930, the U. S. Bureau of Fisheries (Department of Commerce), which was then charged with the responsibility for stocking public waters, had opened a temporary hatchery on a site just outside Cortland and fairly close to Ithaca. The gently rolling area around the new hatchery, at an elevation of about 1,100 feet, encompassed both swamp and woodland--red pine, Norway spruce, hemlock, and a few hardwoods. Several excellent springs and a number of spring-fed brooks in the watershed provided a good flow that could be carried by gravity line to troughs and ponds. By the end of two very successful production seasons the Cortland substation had proved that its location was fine for the rearing of trout. Further, the hatchery had served as a base for feeding, rearing, and breeding experiments made under the direction of Dr. George C. Embody, of the faculty of Cornell University.

Cortland has continued to develop along the two lines so clearly indicated during the early months of its existence. The station's research may be said to have won wider recognition; nevertheless, its production is known to have met a real need.

Research

The success of trout culture at the Cortland hatchery, added to its proximity to a great university, promptly led to the development of the station as a research center. For some time the Bureau of Fisheries had recognized the desirability of improving its trout but had lacked the necessary research facilities and staff. At Cornell University, meantime, the fine potentialities of the nearby Cortland site had been under consideration. Men who were trained in the investigative work desired by the Bureau of Fisheries had pointed out the need for hatchery facilities to supplement their laboratory work; several of these scientists had hoped that the convenient Cortland site would become available to them. At the same time, a third organization, the New York State Conservation Department, had become interested in the advantages of developing a research unit at Cortland--a site known to be good for producing trout and so close to the assistance that might be obtained from Cornell.

In 1932, therefore, the Bureau of Fisheries, the New York State College of Agriculture of Cornell University, and the New York State Conservation Department arranged to pool their resources at Cortland. Dividing its Cortland plant into an experimental unit and a producing unit,

(A) The laboratory and hatchery buildings of the Cortland, New York, Fishery Station.

(B) Two ponds used for holding the brood stock.

(C) Constant-temperature room used for metabolism studies.

(D) Some equipment in the chemical laboratory and the adjoining ether-extraction room.

the Bureau undertook to place hatchery facilities, eggs and fish, and their food supply at the disposal of the experimental unit--as well as to incubate those eggs, rear the fish, and distribute surplus fish at the end of the season. This arrangement would make it possible for successful experimental procedures to receive large-scale tests in the producing unit. Cornell provided the director of research, use of its biochemical laboratory facilities, and special equipment needed for the chemical studies. The Conservation Department's contribution to the project included funds for salaries of the director and his graduate assistant and for the purchase of experimental feeds, laboratory chemicals, and special equipment. The findings of the unit were to be published annually by the Conservation Department as the joint contributions of the three organizations.

Dr. C. M. McCay was provided by Cornell University as Cortland's director of research. A. V. Tunison was the first representative of the Conservation Department to work at Cortland. A hatchery superintendent and fish-culturists were employed for the station by the Bureau of Fisheries.

The cooperative agreement signed in June 1932 called for an investigation to "deal with the digestibility and metabolism of the various nutrients by trout, their vitamin requirements, and with enzymotic and other physiological studies." The reason for this emphasis on the nutritional requirements of trout lay in the need of the hatcheries for new feeding formulas. Trout culturists were well aware that they could secure fine results by feeding an all-meat diet. In view of the rising cost of meat, however, they were finding it more and more difficult to finance such a diet, especially as they were being asked to produce larger and larger numbers of trout. The problem was to replace meat with foods that were less expensive but equally efficient in terms of growth and production.

With the organization of the unit completed and the objectives approved by the cooperators, little time was lost in starting the work. Within a few weeks a small hatchery had been equipped with special troughs, tanks, and other facilities for the desired research. By the end of 1932, between 30 and 40 different diets were being tested on trout at Cortland.

Studies directly related to nutrition formed the initial work of the unit. The digestion and use of fats, proteins, carbohydrates, and minerals; efficiency of food conversion; symptoms of diet deficiencies; establishment of vitamin requirements; use of diet supplements; growth rates of different trout species maintained on various diets; tests of new commercial feedstuffs; and the efficiency of diet binders--these were a few of the investigations begun. Because of the close relationship of nutrition to other factors, however, the program was rapidly expanded to encompass other problems of the trout culturist. Inevitably, in order to assess correctly the nutritional value of various diets, it was necessary to study species differences, anatomical changes, physiological processes, disease-control procedures, drugs and chemicals, vitamin concentrates, food preservation and storage, and feeding and other hatchery practices.

The new unit soon undertook a new approach to the study of trout nutrition. For some 8 years trout culturists had been watching the interrelationships of various feeds, growth rates, and mortalities. In 1934, while continuing to use that method, Cortland initiated a second type of investigation--"chemical balance" studies of trout. Such a method depended on making accurate chemical analyses of the feed ingested by a trout as well as of its excreta. This biochemical approach was useful in such problems as determining the phosphorus and calcium requirements of growing trout or the amount of raw or cooked starch that trout could metabolize. The progress made at Cortland in studies like these drew the attention of biochemists throughout the United States as early as 1936.

Cortland received the benefit of a number of WPA and PWA projects in 1938. A new experimental hatchery was built, and the old hatchery room was remodeled

to suit the needs of the chemical-analysis work.

An outstanding development of this period before Pearl Harbor was the diet known as the Cortland Dry-Feed Mixture No. 6. Intensive trials over several years demonstrated that a diet combining equal parts of this mixture and pork spleen was quite satisfactory in the production hatchery, and that the cost per pound of trout produced was about half that of a diet of beef liver, pork spleen, and salt. The Cortland No. 6 diet offered the hatcheryman one means of reducing the cost of rearing trout. This was particularly welcome during World War II, when meat became more difficult to obtain and more and more people began to seek relaxation on the trout streams. The value of the diet became more obvious, too, with the trend toward stocking streams with legal-sized trout--which required longer hatchery feeding and therefore cost more. The "Cortland diet" quickly won acceptance in trout hatcheries everywhere.

The value of Cortland's work in nutrition research received official recognition in 1944. In that year the three cooperators--the Bureau of Fisheries had been superseded by the Fish and Wildlife Service (Department of the Interior)--reviewed their common enterprise and renewed it with some changes in their respective contributions. At this time the objectives of the experimental unit were restated as being (1) studies of the nutritional requirements of game fishes, (2) investigations of the physiology and biochemistry of fish, (3) development of hatchery diets for fishes, and (4) improvement of fish-cultural practices.

An additional objective--the evaluation of hatchery-reared trout in a stocking program--was approved by the cooperators 4 years later. This amendment to the agenda arose from the desire to improve the survival of hatchery trout after planting, to determine whether various hatchery practices affected the survival rate. An investigation of this kind required that trout reared to predetermined specifications (by the Service) be planted in waters selected for testing (by the Conservation Department and Cornell) by means of creel census and population checks; this project required also that the chemical composition of the trout be determined periodically (by the Service). Which were more efficient for stocking purposes--fast-growing or slow-growing trout? trout fed diets high in protein or trout fed diets low in protein? fat trout or lean trout? The answers to such questions were essential to trout producers as well as to management biologists.

In remodeled, expanded quarters, an entirely new program was begun in 1951. A cooperative agreement with the Atomic Energy Commission had made radioactive isotopes available for the trout research. With these isotopes to "tag" materials, the research staff could undertake more intensive studies of trout physiology, could measure more precisely the utilization of fats and minerals in the trout body. Obviously, the trout culturist could change the diet accordingly if he knew whether the trout absorbed a mineral from the water, how the mineral was used, its quantitative importance, and the length of time it was retained. By the end of the 1956 season, biochemists at Cortland had reported on extensive trials of brook trout held in water that contained radioactive calcium, magnesium, phosphorus, and cobalt.

As new products appeared on the market, Cortland's researchers examined the possibilities for their use in trout culture. Antibiotics, becoming more and more widely used in animal feeds, were tested to determine whether their addition to trout diets produced any benefits. Similarly, the growing use of pellets in many forms of animal husbandry made their trial at Cortland inevitable. Between 1952 and 1956, the station developed better procedures for feeding pellets to fish and demonstrated that a pelleted form of Cortland No. 6 was most satisfactory in the production hatchery.

Dr. Arthur M. Phillips, Jr., who is an employee of the Service, has been the director of the Cortland Station nearly 12 years. D. A. Brockway has been the Conservation Department's representative in recent years. Cornell University has

not had a representative at Cortland for several years but has continued to make university facilities and personnel available for special studies and consultations.

In the first 25 years of its operation, the research unit at Cortland has made possible the saving of thousands of dollars in hatchery food programs. As the Federal hatcheries alone used more than 5,800,000 pounds of fish food during 1956, it is obvious that diet changes involving only a few cents per pound for a particular food have represented real economy. Some diet changes that initially increased the cost of the diet have lowered the production cost. Thus, the inclusion of cod-liver oil at the established level of 3 percent of the diet has increased the rate of growth 20 to 30 percent, reduced the time needed to rear the fish to a given size, and proportionately reduced labor and handling costs. The use of pellets, too, has tended to eliminate the need for large refrigeration plants and reduced by one-third the labor and time otherwise devoted to food preparation and feeding; moreover, food in the form of pellets is completely consumed, with practically no loss of the nutrients. Such advancements as these, in addition to improved feeding methods, have reduced the conversion factor from 4.2 in 1946 to 3.3 in 1956.

Cortland's research has made the hatchery feeding program an effective instrument in preventing the nutritional deficiencies that formerly caused great losses. Studies on vitamin requirements have prevented the costly mortality from such conditions as blue-slime disease, a dietary gill disease, and trout anemia. Chemical studies, by establishing the inability of the fish to handle high levels of starches, sugars, or fats, have demonstrated that the feeding of the more expensive proteins produces a better, healthier trout.

Aside from their efforts to improve the hatchery product, Cortland's workers have completed other assignments that have been more of a service nature for the Fish and Wildlife Service and the New York Conservation Department. Such work has included special bioassays and chemical analyses, as well as tests of many drugs, chemicals, and food supplements. Worthy of mention here are the hundreds of samples of Lake Superior lake trout analyzed for fat content as part of a study to distinguish races. Bioassays of wild fish and fish-food organisms of many species have been made for comparison with hatchery-reared fish and hatchery diets. The Cortland laboratory has cooperated--and still is cooperating--with other laboratories on several long-range research projects. One of these projects involves a study of the productivity of natural waters--a study that is expected to yield dividends in the form of larger populations of wild fish.

Cortland's annual reports--the 25th is now in preparation--are making the work of the research staff available to fishery workers everywhere. In addition to the annual reports, nearly 50 scientific and general papers have appeared in several journals. One of the objectives has always been to publish the results of scientific work in such a manner that the average fish-culturist can understand the material and use it. About 35 papers of this kind have appeared in various issues of THE PROGRESSIVE FISH-CULTURIST. The latest such papers, a series entitled "The Nutrition of Trout," have been of great value and interest to fish-culturists and biologists alike.

The work being done at Cortland has attracted visitors from England, France, Denmark, Sweden, Finland, Poland, Israel, India, Pakistan, Thailand, Japan, the Philippines, New Zealand, Canada, Iceland, Mexico, Bolivia, and Peru. These foreign fishery workers have come to the station for information about trout feeds and feeding, fish-cultural methods, and laboratory facilities.

Within the past year, requests for reprints and for specific information have come by mail from 21 foreign countries--England, Scotland, France, Sweden, Denmark, Norway, Germany, Italy, Austria, Switzerland, Israel, India, Hong Kong, Australia, New Zealand, Union of South Africa, Japan, Canada, Mexico, the Canal Zone, and the Bahamas.

Production

In January 1930, the Bureau of Fisheries began to produce trout in a small frame building near Ithaca, New York. The Bureau administered this new hatchery as a substation of the U. S. Fish-Cultural Station at Cape Vincent, New York. The hatchery supplied trout for stocking streams and for studies in progress at nearby Cornell University.

Upon approval of the cooperative agreement of 1932, the Bureau of Fisheries turned over to the direction of Cornell University the hatchery building then in use at Cortland, such rearing ponds as were necessary, and the desired stock of eggs. By that same agreement, however, the Bureau had accepted responsibility for incubating the eggs and for rearing and distributing surplus fish. These tasks, therefore, as well as the production of fish for the Bureau's distribution program, were assigned to the new production hatchery that was built in 1932.

The production of fish at Cortland was always secondary to, and was never permitted to interfere with, the research program.

As the new hatchery provided nearly ideal conditions for handling trout eggs, within a few years the Cortland unit was receiving and incubating brook, brown, rainbow, and lake trout eggs shipped from Federal egg-collecting centers in Maine, Missouri, Montana, New Hampshire, New Mexico, Vermont, Virginia, and West Virginia, as well as from other stations in New York. After supplying the nearby experimental hatchery with fish of the various sizes and species desired there, the production hatchery forwarded the surplus stock--in the form of fry, fingerlings, yearlings, or adult fish--in accordance with directions issued by the Bureau of Fisheries.

In 1941 the production hatchery began to maintain its own brood stock and take its own eggs, whereas formerly all the eggs handled at Cortland had been shipped there from other stations. With this change, Cortland was rated as an independent fish-cultural station.

The 1950 season marked the beginning of Cortland's outstanding production of brown trout eggs. In 1950 the station distributed more than 1,500,000 brown trout eggs--three times the count of the previous year. Six years later, after transferring some 60,000 eggs to the research laboratory, Cortland shipped more than 2,000,000 eggs to hatcheries in 15 States.

The record of the production hatchery continued to be excellent during the period from 1951 through 1956. Declines in production could be traced to such conditions as failure of eggs received, increase in research program, small carryover of fish, or abnormal mortality among brood and experimental fish. Increases in production were usually due to the presence of adequate numbers of brood fish, the use of a pellet-meat diet, and unusual success in the research program. A favorable decrease in conversion factor was generally attributed to improvement of fish-cultural practices and the use of fish food in the form of pellets.

Throughout the years, the production hatchery has been closely linked to the developments in the research laboratory. Fish produced or eggs put aside for use in the experimental unit frequently did not become available for distribution by the production hatchery later. Too, losses among the experimental fish had the effect of increasing the conversion factor for the production hatchery. Again, the method of feeding pellets and the pellet-meat diet (which resulted in excellent growth, conversion, and saving of labor for the production hatchery) were developed by the research unit. On the other hand, the nature of the experimental program during one year restricted the feeding of pellets to only two lots of fish in the production hatchery.

In-Service Training

A temporary crew of workers took over the fish-cultural and maintenance duties at Cortland in 1945. This temporary crew was composed of Fish and Wildlife Service employees who had been transferred to Cortland from other Federal fish-cultural

stations to receive a year's training in the fundamentals of fish husbandry and related fields. At the conclusion of the training period, the Service reassigned these men to other trout-producing stations.

Since 1946, an in-Service training school has been an integral part of the Cortland program. Groups of carefully selected trainees have studied--under the supervision of the director of research--such subjects as general and fish nutrition, fresh-water biology, physiology, disease identification and control, water analysis, hatchery management, fish-cultural practices (such as spawning, cleaning, feeding), and administrative procedures. The course has combined formal classes (lectures, laboratory periods, and examinations) with supervised manual labor in the care of the station's trout.

The groups accepted for training each year have been small. Nevertheless, the program has made it possible for the Service to place 36 Cortland-trained men in positions of responsibility at Federal trout-producing stations in Maine, New Hampshire, Vermont, Rhode Island, New York, Pennsylvania, North Carolina, South Carolina, Georgia, Tennessee, West Virginia, Ohio, Michigan, Wisconsin, Iowa, Missouri, South Dakota, New Mexico, Colorado, Utah, Wyoming, Montana, Idaho, Washington, and California. This arrangement has made it possible for all these stations to receive the benefit of the latest techniques and procedures Three additional trainees have been assigned by the Service to supervisory duties in the regional offices in Atlanta, Georgia, and Boston, Massachusetts. Limited facilities have made it difficult to extend this opportunity to non-Service personnel, but the course has been completed by four men now employed by the New York Conservation Department, one man who is working for the State of Connecticut, another who is employed by the State of North Carolina, and still another who is working in Ontario, Canada.

Cortland's training school, like its research, has attracted attention abroad as well as at home. Students from Canada, Mexico, Iceland, Bolivia, Poland, and the Philippines have studied fish-cultural methods during at least a portion of the training course.

It should be noted that a number of graduate students at Cornell University receive part of their training at Cortland. Several graduate students majoring in fish culture or some special phases of fishery biology have either done their research at the Cortland Station or had its present director--Dr. A. M. Phillips, Jr. --as their chief advisor.

RAINBOW TROUT BRED IN SALT WATER

In June 1957, Mr. Alfred Petersen, a fish breeder in Denmark, had produced several thousand salt-water-bred rainbow trout in a pond on the island of Hjarno in Horsens Fjord.

Three or four years ago Mr. Petersen bought 35 full-grown rainbow trout from a fresh-water fish breeder and put them in 200-liter barrels of salt water from the island of Hjarno.

Next year, Mr. Petersen put his trout in a small (20 square meters) salt-water pond on Hjarno. The resultant crop of rainbow trout were bright-colored like salmon, with the flesh of a commercially desirable light red.

This year Mr. Petersen built a large (1,600 square meters) fish farm just inside a dam that cuts off the headwaters of a salt-water bay. The pond's walls have openings for inflow and outflow of the tide, though the water is changed regularly by motor pumps when the tidewater is too low. The pond's bottom has deep trenches to permit fish movement at low tide. The trout grow rapidly, receiving minnows to supplement the diet of crustaceans (shrimp and beach fleas) in the water.

OBSERVATIONS ON WILD, LONG-JAW RAINBOW TROUT

Robert E. Lennon
Bureau of Sport Fisheries and Wildlife, U. S. Fish and Wildlife Service
Kearneysville, West Virginia

ANOMALIES IN WILD FISH are not infrequent, but seldom is a certain type observed with regularity in one locale. The occurrence of rainbow trout with markedly elongated lower jaws in the West Prong, Little Pigeon River, Great Smoky Mountains National Park, was first noted during stream surveys in November 1953. Since that time, approximately 2 dozen specimens, 3.4 to 11.5 inches long, have been collected.

The West Prong is a relatively poor trout stream, but its location adjacent to a trans-park highway makes it important in terms of accessibility and fishing pressure. It is steep, rough, and subject to extensive scouring during frequent freshets. Diminished flow and severe icing are common in winter on the upper section at elevations of 3,000 to 4,500 feet, where long-jaw fish are found. Although wild rainbow trout and native brook trout were never abundant in this stream, the populations were very nearly eliminated by an exceptionally disastrous flash flood in September 1951. Their recovery has been slow, and catchable-size rainbow trout were stocked in 1952 and 1953--and brook trout in 1954--to augment the fishery.

Collection and Examination of Long-Jaw Specimens

The long-jaw rainbow trout collected occasionally in the West Prong in 1953 and 1954 were 8 or more inches long, and no details other than length and weight were recorded for them. It was considered possible that they were carryovers from the 1,750 yearling fish stocked in April 1953, in spite of the fact that no long-jaw trout were observed among the hatchery fish when they were planted. When, however, fingerling specimens were captured in May 1955, they provided evidence of a stream population which possessed the long-jaw characteristic. Twelve long-jaw trout were taken in 1955 and 1956, and the length of these fish ranged from 3.4 to 10.0 inches. Three of the fish were young-of-the-year, and the others were 1 to 3 years old. Immature and mature fish of both sexes were also included. The examination of scales showed that all were fish native to the stream.

A detailed examination of the long-jaw trout disclosed that the mandible was generally oversize in relation to the rest of the head rather than elongated at the tip. The mandibles of 7 specimens, 3.4 to 7.7 inches long, extended 1.5 to 6.5 millimeters beyond the tip of the snout (figures 1 and 2). In contrast, the snouts of 50 normal trout of both sexes, 2.6 to 9.2 inches long and 0 to 3 years old, extended anteriorly 0.5 to 3 millimeters beyond the tips of the mandibles. The increased length of the mandibles in long-jaw fish is therefore greater than would be indicated by measurements beyond the tip of the snout. In the larger, long-jaw specimens, the mandibles also extended laterally beyond the maxillary bones of the upper jaw, causing the latter to become somewhat infolded. On the other hand, it is the maxillaries of the normal trout that overlap the lateral borders of the mandibles.

A comparison of the mandibular sensory pores on the jaws of both groups of

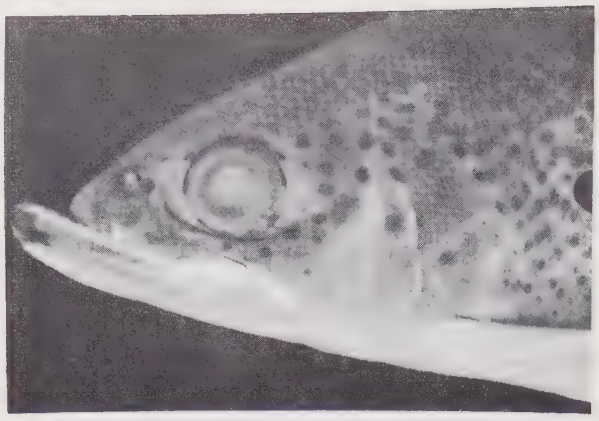

FIGURE 1.-- A 7.7-inch rainbow trout taken in West Prong Little Pigeon River on September 11, 1956. The oversize mandible extended 6.5 millimeters beyond the snout.

fish showed that the numbers and relative positions of pores were similar, but that those on the long-jaw fish were spaced further apart. These pores on the larger of the long-jaw specimens averaged as much as 1.5 millimeters further apart than on normal fish of comparable sizes.

The dentition on the oversize mandibles was in no way unusual. There was, however, some compensatory development of thick skin on the tip of the snout to protect it from the teeth on the lower jaw. This development caused the snouts of long-jaw fish to be slightly longer than those of normal rainbow trout. There was no evidence that the long-jaw fish experienced difficulty in feeding. Their coefficients of condition were close to the average for trout in this stream, and no erosion nor abrasion was observed on the lower jaws.

The relationships between the lengths of head and lower jaw, and lengths of head and snout, were demonstrated by fitting lines to measurements of these parts on 6 long-jaw trout, 3.4 to 7.7 inches long, and 50 normal trout, 2.6 to 9.2 inches long (figure 3). The lower jaw was measured from the posterior end of the left dentary bone to the tip of the jaw. The length of head included the distance from the tip of the snout to the posterior edge of the operculum, excluding the membrane. The length of snout included the distance from the tip to the anterior rim of the orbit. The equations ($y = a + bx$) for head-jaw and head-snout lines on long-jaw trout were

(1) $y = -3.97 + 0.87x$ with standard error of 2.63,

and

(2) $y = -1.54 + 0.29x$ with standard error of 0.58,

respectively. The respective equations for normal fish were

(1) $y = 3.01 + 0.48x$ with standard error of 3.44,

and

(2) $y = 0.49 + 0.20x$ with standard error of 1.32.

The fitted lines (figure 3) show only roughly the extent that the lower jaw and snout may be longer in the long-jaw fish

FIGURE 2.--Young-of-the-year rainbow trout that exhibited the long-jaw characteristic. These specimens, 3.4 to 3.9 inches long, were captured in West Prong Little Pigeon River on September 11, 1956.

than in normal fish. They do, however, confirm the disparity observed in lengths of mandibles in the two groups of fish and indicate a tendency for the mandible to be longer in relation to the head as the long-jaw fish increase in total length. A normal 8.0-inch trout with a head length of 42 millimeters might have a mandible 23 millimeters long and a snout 9 millimeters long, whereas a long-jaw trout of the same length might have a mandible 32.5 millimeters long and a snout 10.5 millimeters long. The mandible in this long-jaw fish would, according to the lines of prediction, extend 6 millimeters beyond the tip of the snout, which is within the range observed on specimens.

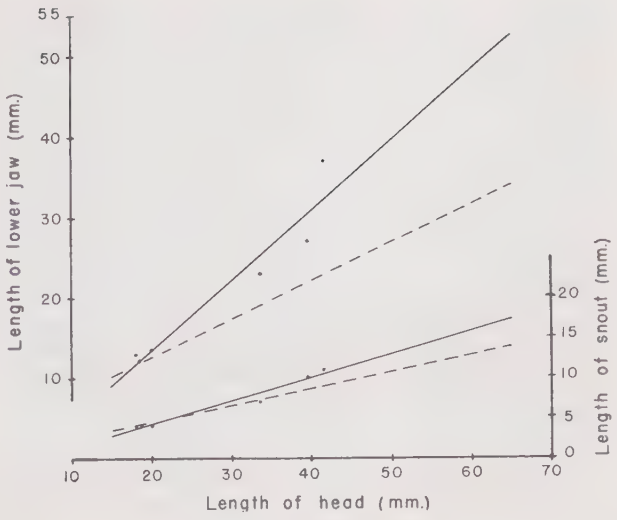

FIGURE 3.--Relationships between the lengths of head and lower jaw, and lengths of head and snout, in 6 long-jaw rainbow trout (solid lines) collected in West Prong Little Pigeon River in 1956 and 50 normal rainbow trout (broken lines) taken in the same and nearby streams in Great Smoky Mountains National Park. Only the points for long-jaw rainbow trout are shown.

Conclusions

No causes for the elongation of the lower jaw have been determined. Extensive collections of rainbow trout have been made in streams of the Great Smoky Mountains National Park in the past 4 years, but no long-jaw specimens have been taken in waters other than the West Prong, Little Pigeon River. Some of the streams have had the same history of old and recent stocking as the West Prong. As the long-jaw condition is found only in wild fish, of both sexes, and in all age groups, it may be either a congenital anomaly or the result of a disease peculiar to rainbow trout in this stream. Evidence relative to either possibility will be gathered whenever fresh specimens are collected.

The association of Gymnodinium brevis with the sporadic mass mortality of fish and other marine animals occurring in the Gulf of Mexico since 1947 is fairly well established. Further, investigation in the laboratory has demonstrated that this dinoflagellate in pure culture is toxic to fish. On the basis of this evidence, it has been proposed that the name "brevis red tide" be used for such mortalities instead of the nonspecific term "red tide," which is used commonly in popular and scientific writing.

Two new techniques that have been proposed for use in the processing of various species of fish include high-level radiation (known also as cold sterilization), which kills all bacteria, and low-level radiation (known also as radiopasteurization), which kills most of the bacteria.

AN IMPROVED PORTABLE TATTOOING DEVICE

Donald W. Chapman
Oregon Cooperative Wildlife Research Unit
Corvallis, Oregon

A SEARCH FOR METHODS USEFUL IN MARKING JUVENILE STEELHEAD TROUT (Salmo gairdneri) has been part of a life history study conducted by the Oregon Cooperative Wildlife Research Unit.

One phase of the Unit's steelhead study required that seaward-migrating fish be trapped and marked at several locations on the Alsea River and its tributaries in Lincoln and Benton Counties, Oregon. It was necessary to use marks which would identify the capture date and trap location when migrants were caught later at downstream points on the river. Injections of dyes and liquid latex, tags, and tattoos were used. Latex injections (Chapman 1957) and tattoos proved most useful.

Tattooing devices as now used were developed by the Washington State Department of Fisheries (Dunstan and Bostick 1956) and used to mark juvenile chinook salmon (Oncorhynchus tshawytscha). The prototype of the machine from which modifications were made was kindly furnished the Unit by personnel of the Washington agency.

In order that the tattoo machine might be used conveniently at the widely separated trap locations, it was necessary that the device be readily transportable, capable of operating on portable-generator power, and easily cleaned after each use.

The Oregon Cooperative Wildlife Research Unit is sponsored by the Oregon State Game Commission, Oregon State College, Wildlife Management Institute, and the U. S. Fish and Wildlife Service, cooperating.

Construction of Device

The device (figure 1) has three main components: Jig-saw vibrator (A), frame and operating table (B), and the needle assembly with tube socket (C).

The frame and operating table shown are fabricated from aluminum alloys. The table is adjustable for height by means of slotted holes in the back supports; it may be shifted from front to rear by using slots at the front of the machine. The operating table swings up and forward for easy access to the needles and tube socket; it has a 10-inch ruler etched on the top surface.

The jig-saw vibrator, as available from mail-order houses, is altered internally by the addition of a weight to the center of the diaphragm in order to reduce operational noise. The weighted diaphragm is shown in figure 2 (E).

The needle assembly (figure 2) consists of a shaft and needles (A), tube socket (B), and brass sleeve (C). The shaft is threaded to the weight on the vibrator diaphragm (E) and is drilled at the outer end to hold ten No. 10 embroidery needles (soldered in place). The brass sleeve encloses the rear portion of the shaft; the tube socket surrounds the forward end. This tube socket may be screwed in or out on the brass sleeve to obtain varied penetration of the needles beyond the face of the assembly, and is held in place by a lock nut. The socket is threaded to hold a pigment tube (figure 3, D) similar to those used for toothpaste or ointment.

The possibility of electrical shock to the machine operator is minimized by use of a drop cord and foot pedal to actuate the

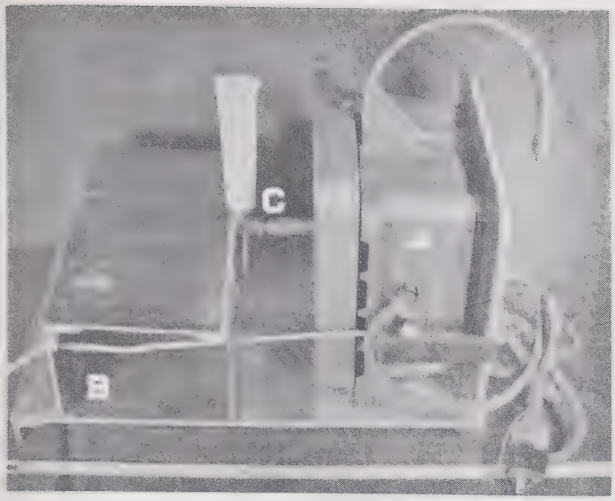

FIGURE 1.--The improved tattooing device.

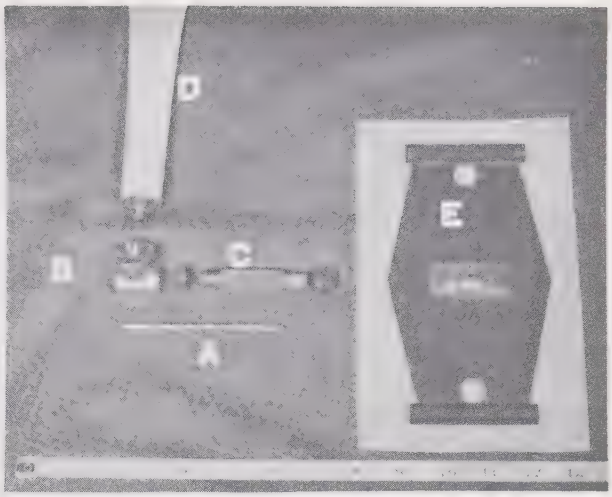

FIGURE 2.--The needle assembly and vibrator diaphragm.

(Photographs courtesy of the author)

vibrator switch. Spring tension on the switch is maintained by the arrangement shown in figure 1.

The tattooing device is easy to transport and may be carried from vehicle to streamside with ease. A 100-foot extension cord was used to connect the machine with a portable a.c. generator mounted on a vehicle.

Pigments for Tattooing

Use of collapsible tubes to hold a pigment supply greatly facilitated marking operations. Titanium dioxide (TiO_2) was the most satisfactory compound used in the tubes, either as a marking pigment or as a vehicle for other colors. The mixture of India ink with titanium dioxide produced a dark gray pastelike substance. This material maintained the proper consistency for at least 3 months when put in tubes. Mixtures of titanium dioxide and trypan blue were also satisfactory.

Dots tattooed with the titanium dioxide-India ink mixture could be recognized as long as 5 months. This pigment showed up well on the ventral surface of juvenile steelhead, whereas the trypan blue mixture was readily recognized on either dark or light portions of the fish.

The marking program on the Alsea River utilized dark gray tattoos on the ventral surfaces of the young migrants. A gray dot was put at the base of a pectoral or pelvic fin to designate 1 of the 4 trap locations at which fish were caught. The date of marking was shown by combinations of tattoos at 1 or more of 10 locations on the ventral surfaces.

Fish to be marked were anesthetized and firmly pressed against the face of the tube socket for about 1 second while the machine was in operation, thus allowing the needles to tamp pigment into the flesh.

As now used, the tattoo devices are limited in that the marks produced last for a maximum period of 5 months. It is possible that a pigment will be developed which will remain recognizable for the lifetime of the tattooed fish.

Acknowledgments

The author gratefully acknowledges the friendly advice and cooperation given him by D. E. Schoeneman and R. T. Pressey of the Washington Department of Fisheries, as well as the invaluable advice and encouragement of H. R. Newcomb of the Oregon State Game Commission. Recognition of assistance is also due Clarence Campbell, of the Oregon State College Farm Mechanics Laboratory, who built the improved machine.

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EFFECTS OF JAW TAGS AND FIN-CLIPPING ON RETURNS OF STOCKED TROUT

To compare the effects of jaw tags and fin-clipping on returns of stocked trout, Arthur E. Newell, of the New Hampshire Fish and Game Department, conducted experiments in 1955 and 1956.

In the 1955 study, approximately half of the brook and rainbow trout stocked were marked with a standard jaw tag, while the other half were marked by removal of the adipose fin. Equal numbers of tagged and fin-clipped fish were then stocked in each of several sites in a typical mountain trout stream. The table shows the returns obtained in a creel census made on weekends and holidays.

For the 1956 study, only rainbow trout were used, but the same stocking procedures were followed.

"There apparently is a difference of 6 percent for brook trout in 1955," writes Mr. Newell, "but tags were subject to loss when anglers cleaned the fish streamside, whereas an adipose fin-clip was always visible. Thus, the difference could not exceed 6 percent, is probably less, and may be insignificant. On the other hand, it was not believed that the 14-percent difference for rainbow trout in 1955 could be attributed to loss of tags while anglers cleaned the fish on the stream.

"The data for seven stockings of legal-sized fin-clipped and tagged rainbow trout in 1956 certainly indicate that use of a jaw tag on hatchery-reared rainbows has no greater influence on the returns of these fish to the creel than fin-clipping."

COMPARATIVE RETURNS OF TAGGED AND FIN-CLIPPED BROOK AND RAINBOW TROUT

Species	Date stocked	Number stocked		Returned			
				Fin-clipped		Tagged	
		Fin-clipped	Tagged	Number	Percent	Number	Percent
	1955						
Brook-----	May 12	488	500	143	29.30	116	23.20
Rainbow--	May 13	250	250	105	42.00	69	27.60
	1956						
Rainbow--	May 25	250	250	58	23.20	45	18.00
	June 13	250	244	76	30.40	72	29.51
	June 19	225	250	55	24.44	61	24.40
	July 2	193	192	34	17.62	39	20.31
	July 25	200	200	60	30.00	49	24.50
	Aug. 2	200	200	34	17.00	28	14.00
	Aug. 15	147	150	19	12.93	22	14.67
Totals(1956)--		1,465	1,486	336	22.94	316	21.27

THE NATURAL PROPAGATION OF NORTHERN PIKE IN SMALL DRAINABLE PONDS

D. B. McCarraher
Nebraska Game, Forestation and Parks Commission
Bassett, Nebraska

TO OBTAIN INFORMATION ON THE HATCHING SUCCESS AND FINGERLING SURVIVAL OF THE NORTHERN PIKE (Esox lucius) in small drainable ponds, experiments were initiated at the State Fish Hatchery, Valentine, Nebraska, during the spring seasons of 1955 and 1956.

All the ponds used in this work were winter-fallowed, providing areas without fish populations. At no time in 1955 or 1956 were forage fish added to the ponds.

Adult spawner pike for the ponds were obtained from Mothers Lake (in Cherry County, Nebraska) in 1955 and from Big Alkali Lake (also in Cherry County) during 1956. All breeder pike were ripe when they were placed in the ponds. The average length of the females in 1955 was 26 inches; that of the males, 22 inches. The spawners used during 1956 were larger, the females averaging 32 inches and the males 25 inches in length. Female pike from Big Alkali Lake, in the 30- to 35-inch group, represented the 1952 year-class.

Individual Pond Histories

Pond A (1955)

Pond A, containing about 2.6 surface acres, was stocked on March 30, 1955, with 4 female pike (average length, 28 inches) and 7 males (average length, 22 inches). All females were ripe.

Spawning was not observed along the shore, but the spawning period was believed to be April 15 through April 18. On the basis of a normal 14-day hatching period at 52° F., fry would have appeared from April 29 through May 2. Fingerling pike were first observed along the shore of the pond on May 9. These averaged 31 millimeters in length, the maximum being 37 millimeters. On May 14, the fish had grown to an average size of 1.6 inches. All the adult pike except 1 female were removed from the pond. Removal by hook and line proved time-consuming; a 250-foot gill net was used with excellent results.

On May 18 this pond was drained. The advanced size of several fingerlings indicated the occurrence of cannibalism. The largest pike fingerling removed was 3.3 inches in length, whereas the average was only 1.7 inches.

Total production of fingerling pike for this pond was 4,900, or a percentage survival of 3.3 from an estimated egg production (see Carbine 1944) of 148,000. All females were in a spent condition upon their removal from the pond.

Predation on the young northerns by the adult did not appear excessive until the fry were about 20 millimeters in length. Analysis of the stomachs of the adults showed some fingerlings longer than 20 millimeters, though the numbers were insignificant. The adult pike were feeding mostly on the various species of frogs that inhabited the pond and marginal area. The predation of water beetle larvae, Dytiscidae, on pike fingerlings was observed during the draining but, because of the limited number of the larvae in the

pond, should not be considered a limiting factor. Frogs, turtles, and fish-eating birds--all took their toll of young pike, in numbers undetermined.

In pond A, as in the other ponds, a large population of Ostracoda was present from May 1 to the draining dates. No species of Cladocera or Amphipoda were noted in the pond. The tadpole stage of frogs and toads was common from April 27 through May 10.

Submergent aquatic vegetation in the pond was limited to Chara, Potamogeton pectinatus, and filamentous algae. Emergent vegetation was primarily broad-leaf cattail (Typha latifolia).

The pH reading was 8.8.

Pond B (1955)

This pond was partially fertilized by the addition of 300 pounds of barnyard manure.

Pond B, about 1 acre in surface water, was stocked with 4 male and 2 female pike on April 3. The average length of the males was 22 inches; that of the females, 24 inches. Both female fish were ripe with egg flow upon handling.

The estimated spawning period here was the same as for pond A, or April 15 through April 18. The hatching period in this pond was also similar to that in pond A, though the last fry did not appear until about May 4.

On May 9 the first fingerlings, averaging 29 millimeters in length, were noted. Throughout the fingerling stage in this pond, the averages were consistently 3 to 22 millimeters smaller than those of the fingerlings reared in pond A.

All the adult pike were removed before this pond was drained. Hook-and-line fishing accounted for only one pike; the remaining adults were harvested with a gill net. That both females had successfully spawned was evident upon examination of the ovaries.

The stomach of the 25-inch female pike contained 2 Dytiscidae larvae, 3 fingerling pike, and 1 frog. The stomach of the 23.5-inch pike contained 1 fingerling pike (34 millimeters) and 1 frog.

Pond B was drained on June 2. The crop of fingerlings numbered 1,946, indicating a percentage survival of 3.3 from an estimated egg production of 58,000.

The average size of these fingerlings was 2.3 inches; the largest recorded was 3.3 inches.

Predation by adult fish and aquatic invertebrates was not considered an important limiting factor in this pond. Dytiscidae larvae appeared more numerous than in pond A, and there was a notable number of crayfish.

A heavy "bloom" of Ostracoda appeared on April 30 and persisted until drainage on May 2. Though Amphipoda had been introduced into the pond on April 11, few were observed 2 days later.

The pH reading was 8.6 on April 16; 8.1 on June 2.

Pond C (1956)

This rearing unit contained 1 surface acre of water and had an average depth of 2.5 feet. Pond C was stocked on March 23 with 5 adult females and 10 adult males. The first sac fry were observed 19 days later (April 12). Visual examination of the fry revealed that they were 4 to 5 days old. It became apparent that all the spawners were in a spent condition within 1 week after their introduction to the pond.

This pond was not fertilized with manure.

Plankton samples were made several times. The findings revealed only a moderate zooplankton population throughout the study. Cladocera were most numerous; then the Copepoda.

On May 29 this unit was drained and 1,700 fingerling pike were harvested. As the egg production had been estimated as 330,000, this crop represented a percentage survival of 0.5. The average length of the fingerlings was 2.6 inches, their range being from 1.5 to 3.1 inches.

All ripe female pike were known to have spawned in this pond.

The water chemistry of pond C showed a mean pH of 8.6 and a total alkalinity of 125 parts per million.

Pond D (1956)

Pond D contained 1.5 surface acres and had a mean depth of 2.7 feet. Sago pondweed (Potamogeton pectinatus) and Chara were thriving 4 weeks after the initial filling of the pond.

The pond was stocked with 4 females and 9 males.

Barnyard manure (1,600 pounds) was broadcast throughout the pond basin.

Sac fry were first located on April 25, or 32 days after the introduction of the breeders. When the fry were located, their mean length was 11 millimeters. On May 6, the fry were 15 to 17 millimeters long; on May 17, the mean length was 25 millimeters.

On May 24, the pond was drained and 5,050 pike fingerlings were harvested. As the egg production had been estimated as 240,000, this crop represented a percentage survival of 2.1. The mean total length of these fingerlings was 1.5 inches.

External examination of adult females revealed a successful spawning effort in pond D.

Food of Young Pike in the Valentine Rearing Ponds

The food habits of young pike changed drastically as they increased in size; the young pike often displayed several food-preference stages. After the pike had absorbed the yolk sac and until they were 1.2 inches in length, they readily consumed entomostracans (mainly Copepoda). In the next feeding stage, which occurred during the period of growth from 1.3 to 2.6 inches in length, the food appeared to consist mostly of aquatic insect larvae (Odonata, Chironomidae). When the fish were 2.6 inches and larger, the diet was composed almost entirely of other young pike and available invertebrates.

It was interesting to note that the entomostracan (Ostracoda), though plentiful in all rearing units, was seldom utilized by the growing pike.

The foregoing statements are based on the examination of 220 fingerling pike stomachs during the 2-year period.

Conclusions

The use of ripe northern pike spawners in hatchery ponds offers great promise as an economical and efficient method of production. Though the resultant production of fingerling pike is not high in comparison with that of standard egg-hatching procedures used by hatcheries, it does indicate that controlled natural production will furnish, for stocking purposes, a number of fingerling fish.

Implications are that the fingerlings should be cropped when the pike have reached 2 inches in length. To attempt to rear the fingerlings to a larger size is feasible, but in doing so the total number of pike per pond is greatly reduced. The question often arises, whether it is more economical (an administrative expression) to stock a few hundred 6- or 7-inch or several thousand 2- to 3-inch pike in a lake.

Present results do not suggest using more than 5 females per pond (1 acre). There is apparently no direct correlation between the use of additional females and the total crop of fingerlings produced. There undoubtedly is a relationship between the fecundity of the brood stock and the total number of fingerlings produced; therefore, it is especially desirable to use only ripe fish in this method of propagation.

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MAINTENANCE OF IMMATURE SEA HERRING IN CAPTIVITY

Alva E. Farrin, Leslie W. Scattergood, and Carl J. Sindermann
Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service
Boothbay Harbor, Maine

MANY MARINE FISHES are notoriously difficult to maintain for long periods of time under aquarium conditions, even when running sea water is available. In this category has been the sea herring (Clupea harengus), an extremely fragile fish for experimental purposes. In the course of several years' work with certain diseases and parasites of immature fish of this species, experiments with live herring held in the sea-water tanks of the Boothbay Harbor (Maine) Laboratory of the U. S. Fish and Wildlife Service have proved necessary and instructive. To carry on this work, it has been vital to evolve a successful technique for holding fish for extended periods. Some of the information gained may be of use to other marine fishery investigations.

Our sea-water tanks are of pine construction and of both circular and rectangular design. The first tanks we used were rectangular; but a trial with circular tanks clearly demonstrated that the latter were to be preferred because they were about half as expensive, much tighter, more easily moved, and provided a better circulation of water. We have 4 rectangular tanks of approximately equal dimensions -- about 11 feet in length, 3 feet in width, and 2.5 feet in depth. The water capacities range between 470 and 490 gallons. We have 16 small circular tanks, each with approximate diameters of 3.5 feet and depths of 2.5 feet. The capacities of the small tanks are between 100 and 110 gallons. There is also a large circular tank, 9.5 feet in diameter, 4 feet deep, with a capacity of 1,590 gallons. Each rectangular tank has an upright drainpipe near one end; each circular tank has a drainpipe in the center.

Each tank is cleaned several times a year. On these occasions, the fish are transferred from one tank to another and the inside surfaces of the first tank are scrubbed and washed thoroughly with formalin and then given a coat of black asphalt paint. In this manner, marine-borer damage is kept at a minimum.

In the initial efforts to hold live herring, we felt that perhaps freshly caught herring would adjust themselves more readily to captivity if they were kept in

semidarkness for several days; consequently, we equipped each tank with a hinged cover. However, these were later removed when we could see no noticeable difference in survival in covered or uncovered tanks. As the tanks are inside the main laboratory building, they are never exposed to direct sunlight.

Salt water is supplied by a direct-flow system utilizing a centrifugal pump. The rectangular and large circular tanks are each furnished with about 10 gallons of water per minute, whereas each of the small circular tanks has about 5 gallons per minute. All tanks are equipped with air stones connected to either 110-volt a.c. or 6-volt d.c. air pumps. The 110-volt system is of value when the laboratory's water-pumping system fails, and the 6-volt pump (which operates from a storage battery) is used during periods of complete electrical failure. With these air systems, we have kept herring alive for several days when the supply of salt water has failed.

Usually the herring are caught within several miles of the station. These fish, of age group 0 or 1, from 2 to 8 inches in size, are dipped with a bucket from a seine net into 10-gallon steel milk cans, which are equipped with an air supply in warmer weather. The fish are transported immediately to the laboratory by boat or car. About 20 to 50 fish are put into each can. Great care must be taken to avoid rough handling during capture and transport, or heavy mortalities will result. The herring are put into the large rectangular tanks, which serve to hold the fish prior to their use in experiments. Normally, about 200 to 500 fish, depending upon their sizes, are kept in these holding tanks. In the small circular tanks in which we maintain experiments, about 25 fish are held.

After experimenting with various foods, such as ground liver, live mysids, and cat food, we have selected ground sea mussels as the principal diet for herring. The raw mussel meats are removed from the shell, macerated in a food blender, then allowed to cool to near the freezing point before being fed. The resultant product is buoyant and palatable to the fish, and little is lost in solution. Not all the food is eaten by the herring, for they consume only floating particles; food dropping to the bottom is ignored. During the summer, when the water temperature ranges from 16° to 18° C., about 15 grams of food per fish is put in the tanks daily. In winter, when the water temperature may drop to a level of 1° to 3° C., the food is reduced about one-third. Satisfactory results have been obtained by feeding three times a day. An addition of yeast extract is included in the diet at present.

On herring in the experimental tanks certain ectoparasites have been noted--the parasitic copepod Caligus rapax on the body surface, and the monogenetic trematode Gyrodactylus (sp.) on the gill bars and mucous membranes of the oral cavity--but these have not been definitely associated with increased mortality.

Bacteremias, with tail rot and sloughing of the skin as external symptoms, have been responsible for mortalities of experimental fish in the past. Terramycin has been effective in reducing such bacterial infections. A dose of 1.5 milligrams per gram of herring is added to 1 feeding daily immediately before it is made available to the fish. Other antibiotics and sulfas have been tested, and some--with the exception of sulfamethazine--have been effective.

The methods described above provide survival and growth of immature herring under artificial conditions--so that after an initial transfer loss, the tank population is relatively stable for periods as long as 2 years.

Exploitation of the Newfoundland cod fishery began at the dawn of the 16th century.

AERIAL FISH DISTRIBUTION IN A MONTANA LAKE

R. O. Cooper
Montana Department of Fish and Game
Helena, Montana

TIBER RESERVOIR is a newly impounded lake in north-central Montana. The lake will cover 23,000 acres when filled to capacity.

Prior to impoundment, a rehabilitation project in the drainage was undertaken by the Montana Fish and Game Department to remove rough fish. In restocking this reservoir, 5 tons of rainbow trout (more than 4 million fish) were distributed during the summer of 1956.

This reservoir, though fairly accessible, is reached by few all-weather roads. It was thought that aerial planting of this lake might give a better distribution of fish and be more economical. In Montana, fish have been airplanted for many years, but only in small numbers and in lakes inaccessible to ground vehicles.

It was decided to transport the fish from Great Falls, where there is a paved concrete airport and an accessible fish hatchery. A Cessna 180 airplane, with special camera port, was used. The flying distance from Great Falls to Tiber Reservoir is approximately 65 miles.

Sheet aluminum was used to construct a 94-gallon tank to fit this airplane. The tank was made cylindrical for ease of fabrication and because the shape would minimize "sloshing." Internal baffles were not used. Fish were aerated by compressed oxygen metered through 4 cylindrical carbon rods 9 inches long and 4 inches in diameter. Oxygen pressure through the carbon rods was 4 pounds per square inch. An electric air pump was used to bubble air through the tank at intervals and thus agitate the fish so they would not remain too long in any unaerated part of the tank.

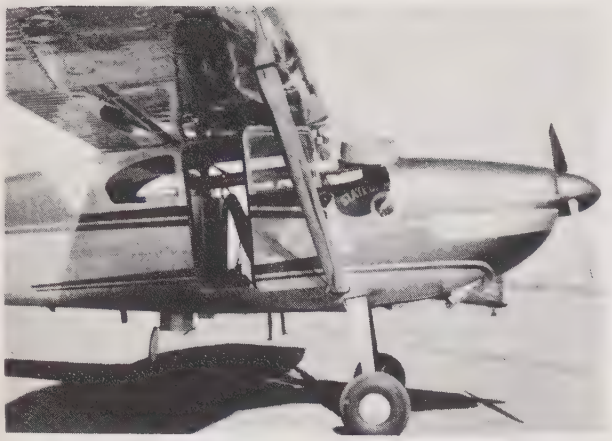
Fish were transported on a 35-minute flight at the rate of 2.75 pounds of fish per gallon of water. No ill effects to the fish were apparent. A normal load was 200 pounds of fish and 55 gallons of water. Ice was used to keep water temperatures in the tank between 40° and 50° F.

As a test for possible delayed mortality, fish were held in the planting tank under simulated flight conditions for a period longer than the expected flight. The fish were then returned to the hatchery tank, where they were observed for several days. No significant mortality was apparent.

The fish were usually dumped from altitudes of 200 to 300 feet at an airspeed of about 80 miles per hour. The tank emptied in about 3 seconds, through a 10-inch dump valve vented through the camera port in the floor of the airplane. Upon dumping, the plane rose rapidly and the abrupt change in control-wheel load made necessary immediate retrimming of the stabilizer. Fish were usually planted in the littoral zone of the lake.

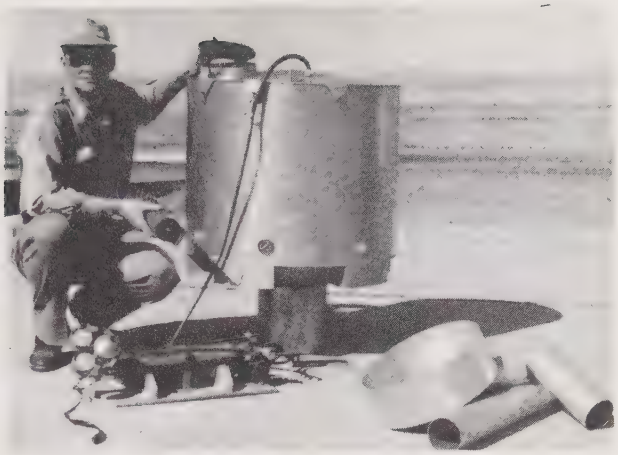
The plane was somewhat overloaded by CAA standards. The allowable gross weight was 2,550 pounds in normal category, whereas our take-off weight often exceeded 2,800 pounds. There was more concern about the overload on the tires than about the overload when airborne. The plane was flown in moderately rough air, and landings were not attempted at full gross weight.

The fish used for this project were raised at various hatcheries in the State. When the fish at a hatchery became mature enough to plant, they were transported



The tank is installed, with the loading funnel in place.

(Photographs courtesy of the author)



The unit has been removed from the plane. The break-down loading funnel and aeration unit are in the foreground. The pilot holds a carbon aeration rod. Cables and turnbuckles are used to secure the tank in the plane.

by truck to the Great Falls Hatchery. Occasionally the fish were hauled 500 miles and were in the truck more than 9 hours. The usual procedure was to wait until about 2 tons of fish were accumulated at the Great Falls Hatchery and then airplant them in a day or two. The size-to-weight ratio of the planted fish was about 400 fish to the pound.

After planting, the tank was removed from the plane and routine flight assignments were continued. The fish tank could be removed or installed by one man in less than an hour.

It is difficult to compute an exact cost analysis. However, 200 pounds of fish could be air-transported for approximately $25, as compared with a cost of $33 for truck transportation. It is estimated that, in an equal period of time, eight times as many fish could be moved by airplane as by truck.

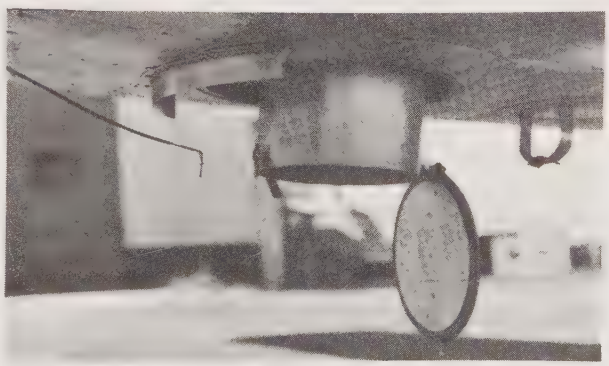
At present there is no exact information on the survival of fish, but the reservoir is already furnishing excellent sport fishing.

A continuation of this planting operation is scheduled for this reservoir in 1957.

Acknowledgments

Thanks are due to Vernon Campbell, hatchery foreman, Montana Department of Fish and Game. Mr. Campbell's cooperation and assistance in working out details of the unit design and operating procedures are greatly appreciated by the author.

Thanks are due also to the Johnson Flying Service of Missoula, Montana. The Johnson Flying Service contributed to the work by constructing the fish tank and assisting in the unit design.



The 10-inch dump valve is tripped by pulling the pin. A door stop is set at the rear of the dump port.

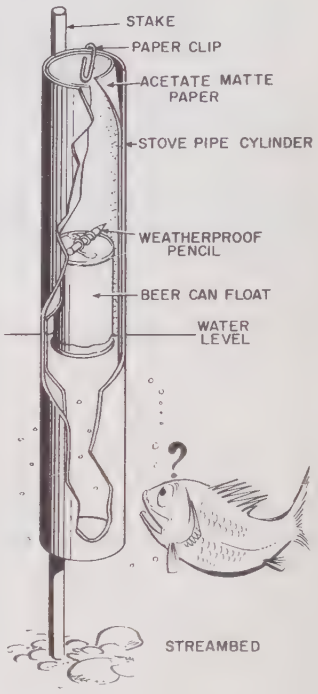
MAXIMUM - MINIMUM WATER GAUGE

Dams are being placed on more and more rivers and streams in this country. In the circumstances, the fishery manager occasionally finds it necessary to measure the fluctuation of the water level as various quantities of water are released into a waterway. To record such fluctuations, the Wyoming Game and Fish Commission uses a pencil attached to a float that moves up and down within a metal cylinder and makes suitable marks on its paper lining.

Thomas H. Leik, fishery biologist in the employ of the Commission, has submitted the following description of the device:

"The float used is an empty beer can that has been soldered shut. The pencil (waterproof) has been fastened in the desired position by winding wire about the pencil and then soldering the wire to the top of the can. The paper cylinder is made of acetate matte (0.005-inch) which will not disintegrate in water and will take markings while under water. The metal cylinder is a section of 3-inch stovepipe. The length of the stovepipe cylinder should be longer than any of the anticipated fluctuations. One gauge, as shown here, costs $0.65.

"Float and cylinders are held in position by wiring the metal cylinder to a post, bridge support, or similar upright in the streambed where water-level fluctuations are to be recorded. The low cost per unit permits more detailed study of an area."



(Drawing courtesy of Mr. Leik)

A PRELIMINARY NOTE ON THE USE OF DI-N-BUTYL TIN OXIDE TO REMOVE TAPEWORMS FROM FISH

The following list of publications should have been presented with Mr. Ray Allison's article, "A Preliminary Note on the Use of Di-n-Butyl Tin Oxide To Remove Tapeworms From Fish" (volume 19, number 3, pages 128-130):

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1956. The removal of chicken tapeworms by di-n-butyl tin dilaurate. Poult. Sci. 35 (1): 64-73.

Jones, L. M.
1954. Veterinary pharmacology and therapeutics. xiii, 524 pp. Iowa State College Press, Ames, Iowa.

McKernan, D. L.
1940. A treatment for tapeworms in trout. Prog. Fish-Cult. 50: 33-35.

Moskey, H. E., and P. D. Harwood
1941. Methods of evaluating the efficacy of anthelmintics. Amer. Jour. Vet. Res. 2 (2): 55-59.

Reid, W. M.
1940. Some effects of short starvation periods upon the fowl cestode, Raillietina cesticillus (Molin). Jour. Parasitol. 26 (6): 16 (supp.).
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